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Developing, refining and feasibility study of mobile app to support asthma self-management (A4A – APP for Asthma)

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Declaration

I hereby declare that this thesis was composed by me and is entirely my own work. It has not been submitted for any other degree or professional qualification.

Hui Chi Yan
Abstract

Background: Self-management with an action plan, as opposed to passive self-monitoring, improves health outcomes. However, engaging patients is challenging. Mobile technology, incorporating education, personalised asthma action plans and facilitating professional support, is an option for supporting asthma self-management. Clinical research has focussed on health-related outcomes rather than informing the features that patients want and will use in a self-management app. Technology developers focus on user engagement as opposed to developing telehealth based on clinical evidence, leaving patients struggling to choose safe telehealth to support their asthma self-management. Risk aversion results in legislation that can be a barrier to the development of asthma apps.

Aims and objectives: Using phases of the MRC Framework for developing complex interventions, and the Oxford app roadmap to develop a prototype app, I aimed, from clinical, patient, technology and legislative perspectives to:

- (Phase 1) Identify the evidence base
- (Phase 2) Model key aspects of app development
- (Phase 3) Explore the feasibility of a mobile app to support self-management

Methods:

- (Phase 1) Systematic review, online social forum analysis, asthma apps review, and legislation regulation review were used to identify evidence. Results were analysed with reference to the PRISMS taxonomy of self-management support.
- (Phase 2) Using results from phase 1, and with the advice of lay and professional advisory groups, I made decisions about the design of the prototype app and the feasibility study in phase 3. I also reviewed the legislative issues regarding self-management app development.
- (Phase 3) I undertook a feasibility study of using asthma mobile apps. Within the three-month feasibility study, five practices in Lothian/Oxford and Asthma UK’s social media invited adults with active asthma to try out our prototype app. I observed patient’s download rate and app usage. Of the patients recruited from practices, I purposively sampled patients (based on age/sex, experience of asthma, current self-management and technology use) and interviewed them before and after using the app for one month about their preferred features. Interviews were transcribed, and thematically analysed with reference to the PRISMS taxonomy of self-management support.
Results:

- (Phase 1) Telehealth was at least as effective as traditional approaches to supported self-management. Most asthma patients using online social forums commented on self-monitoring features, such as logging peak flow and symptoms, as opposed to self-management features. No one explicitly discussed asthma action plans though some patients were positive to the apps which had incorporated an action plan. Similarly the most downloaded asthma apps offered self-monitoring features rather than action plans. Current medical device legislation is ambiguous: it is unclear if apps with an action plan are ‘medical devices’.

- (Phase 2) The final prototype app included the Asthma UK asthma action plan and monitoring features such as the morbidity questions of the Royal College of Physicians three questions, peak flow, use of reliever inhaler, other medication use and lifestyle status. A mixed method approach was chosen for the feasibility study.

- (Phase 3) 111 asthma patients used the prototype app. The ownership of action plans increased 43% to 63% after the study. Most patients preferred digital to paper action plans though the digital format did not improve usage. Action plans and monitoring features were the most ‘wanted’ features by patients, GPs, asthma nurses and the administration staff in the practices. Some patients also ‘wanted’ more advanced features such as predictive exacerbation warnings, identifying precise triggers, learning about what caused/affected their asthma.

Conclusions: Mobile apps are a feasible option to support asthma self-management. Ease of access to download is the key to adoption as well as sufficient motivation (e.g. personal invitation from their GP or asthma nurse). Motivation (specifically GP and asthma nurse’s encouragement and perception of benefit) is the key to adherence, but it will be more effective if the app is easy to use.

Action plans and self-management features were the most ‘wanted’ features by patients and professionals. Other features that patients ‘wanted’ varied; one size does not fit all. Advanced features might encourage on-going use of asthma apps to support self-management. Choice of features, service promotion and service deployment should be considered carefully when implementing mobile app in ‘real world’ setting. The key technological barriers were to provide seamless Wi-Fi and to connect the app with the practice’s software platforms. ‘Medical device’ legislation is currently a barrier for self-management app development, further discussions with all stakeholders is needed to reach consensus on risks involved in incorporating action plans in an app.
Lay summary

Supported asthma self-management including an action plan (traditionally paper-based) helps people look after their asthma. As well as watching symptoms and logging peak flows and medication use, an action plan completed with a nurse or doctor advises patients how to adjust their treatment when their symptoms change. Although clinical evidence shows that supported self-management improves asthma outcomes, for many reasons only a few people have action plans.

I thought mobile apps may be able to support asthma self-management.

There are some studies that have developed and tested asthma apps but they were very clinically-focussed. There are also many eye-catching asthma apps in the apps markets but most of them do not have clinical evidence to prove their effectiveness. People are unsure which app is safe for them. Current legislation is risk averse which is a barrier to development of self-management apps.

Therefore, in this study, I aimed to
   a) develop a prototype app,
   b) explore if it is feasible to use mobile apps to support people to look after their asthma and
   c) find out which features attracted patients to download and continue to use the asthma app.

Firstly, I reviewed the health impacts from past clinical studies, conversations in online discussion forums, features of asthma apps in the Android and iOS market and the legislation documents for healthcare apps. This showed me that apps are a safe way to support asthma self-management for adults. People discussed the common logging features of apps, but action plans were not mentioned.

Secondly, I consulted patients, GPs and asthma nurses to help me develop a prototype app. My prototype app allowed people to log their asthma symptoms, peak flow, use of reliever and preventer inhalers, lifestyle status and we also included the Asthma UK action plan which we suggested people should ask their asthma nurse to help them complete.

Thirdly, I used two strategies to recruit people to use the prototype app: through general practices in Lothian and Oxford; and Asthma UK’s social media such as Facebook and Twitter. 87 people responded to social media prompts, but they soon stopped using the app. Only 24 people were recruited by their practice, but they were more likely to go on using the app. I interviewed people who used the app, and their GPs and asthma nurses who both told me they wanted monitoring features and an action plan on an app. Advanced features such as predicting high risk of attacks, identifying triggers, and helping them find out what affected their asthma were also ‘wanted’ by patients.

In conclusion, mobile apps can support people to look after their asthma, but one size does not fit all. Flexible designs will enable apps to meet the needs of a broader range of patients.
2.3.2 Phase 2: Modelling key aspects to develop an app prototype and the feasibility study (Chapter 7) ................................................................. 49

2.3.3 Phase 3: Three month feasibility study (Chapter 8-9) ........................................ 50

2.3.4 Discussion (Chapter 10), implications (Chapter 11) and conclusion (Chapter 12) ................................................................. 50

Chapter 3 (Phase 1) Clinical perspective: a systematic review of controlled telehealth studies to explore the clinical effectiveness of mobile technologies to support asthma self-management ................................................................. 51

3.1 Aim of this systematic review ........................................................................... 52

3.2 Method .................................................................................................................. 52
   3.2.1 Search Strategy ..................................................................................................... 52
   3.2.2 Screening ............................................................................................................. 54
   3.2.3 Data extraction .................................................................................................... 54
   3.2.4 Risk of bias ........................................................................................................... 54
   3.2.5 Dealing with potential studies with an abstract only ........................................... 54

3.3 Data synthesis and analysis .................................................................................. 55
   3.3.1 Meta-analysis ..................................................................................................... 55
   3.3.2 Narrative synthesis ............................................................................................. 55
   3.3.3 Assessment of clinical importance ...................................................................... 55
   3.3.4 Data presentation (bubble plot versus harvest plot) .......................................... 56
   3.3.5 Interpretation ...................................................................................................... 56

3.4 Results ................................................................................................................... 56
   3.4.1 Included studies .................................................................................................. 56
   3.4.2 Characteristics of included studies ..................................................................... 57
   3.4.3 Risk of bias .......................................................................................................... 64
   3.4.4 Participants .......................................................................................................... 66
   3.4.5 Interventions ....................................................................................................... 66
   3.4.6 Comparisons ....................................................................................................... 66
   3.4.7 Clinical outcomes ............................................................................................... 67
   3.4.8 Application features in the included interventions ............................................ 69
   3.4.9 Application features associated with the health-related outcomes of the included intervention ................................................................. 73
   3.4.10 Adoption and adherence to usage ................................................................. 75
   3.4.11 Adoption and adherence to the intervention ................................................. 75
7.4.3 Deciding on the approach to data analysis .......................................................... 152
7.4.4 Choice of outcome measures for the quantitative study and sample size calculation .................................................................................................................. 155
7.5 Potential risks and burden of the three months feasibility study .......................... 155
Chapter 8  (Phase 3) Three months feasibility study – method .................................. 158
8.1 Method ......................................................................................................................... 159
8.1.1 Ethical approval ...................................................................................................... 159
8.1.2 Setting ..................................................................................................................... 159
8.1.3 Study design .......................................................................................................... 159
8.1.4 Practice recruitment .............................................................................................. 160
8.1.5 Nurse training ....................................................................................................... 160
8.1.6 Patient recruitment ............................................................................................... 161
8.1.7 Professional recruitment ....................................................................................... 162
8.1.8 Online consent for reviewing patients’ usage on app ........................................... 163
8.1.9 Consent to interviews ........................................................................................... 164
8.1.10 Qualitative data collection and analysis ................................................................ 164
8.1.11 Quantitative data collection .................................................................................. 169
8.1.12 Data analysis ........................................................................................................ 171
8.1.13 Data interpretation .............................................................................................. 171
Chapter 9  (Phase 3) The results of the three months feasibility study and exploring the legislation issues ................................................................. 173
9.1 Recruitment and participants’ characteristics ......................................................... 173
9.1.1 Patient recruitment (streams A, B and C) ............................................................ 173
9.1.2 Patient characteristics (streams A, B and C) ....................................................... 176
9.1.3 Patient characteristics (stream A) - for interview ............................................... 178
9.1.4 Practice recruitment ............................................................................................. 179
9.1.5 Characteristics of the healthcare professionals .................................................... 180
9.2 Impact on care and perceived feasibility of the app to support self-management (Objective 1a) ............................................................................................................. 181
9.2.1 The feedback from the final questionnaires ....................................................... 181
9.2.2 The feedback from participants collected from the enquiry message box, email enquiry, our discussion forum and Asthma UK Facebook .................. 182
9.3 The attractiveness of the app prototype to patients recruited via their practice or social media (Objective 2a) ................................................................. 182
9.3.1 Adoption rate ................................................................. 182
9.3.2 Practice: exploring the low adoption rate via consultations .......... 185

9.4 The adoptive and adherent features that influence patient engagement with asthma self-management (Objective 2b) ................................................................. 187

9.4.1 Using theory to understand the triggers, motivation and ability leading the patient to adopt the app ................................................................. 187
9.4.2 Exploring why participants didn’t try out our app? ......................... 190
9.4.3 Adherence rate ..................................................................... 191
9.4.4 Using theory to understand the triggers, motivation and ability leading the patients to adhere to using the app ................................................................. 192

9.5 The features that patients and professionals would like added/excluded mapped to the PRISMS taxonomy (Objective 1b) ................................................................. 198

9.5.1 Patient participants’ rating of the different features ......................... 198
9.5.2 Features usages ..................................................................... 199
9.5.3 Patients’ use of action plans and perceptions of self-management ........ 204
9.5.4 Features of the app related to the PRISMS taxonomy ......................... 206

9.6 To explore the technological barriers and facilitators to using an app for supporting self-management in clinical practices (objective 3) ................................................................. 219

9.7 To explore the legislative barriers to developing an app to support asthmatics self-management (objective 4) ................................................................. 221

9.7.1 What do patients think of the risks from an asthma app? ................. 221

Chapter 10 (Phase 3) Discussion ................................................................. 222

10.1 Summary of findings ................................................................... 222
10.2 Limitations of the three months feasibility study ............................... 226
10.3 Main strength of the three months feasibility study ............................ 228
10.4 Critical assessment of the qualitative study ....................................... 230
10.5 Interpretation of findings in relation to previously published work .......... 233

10.5.1 Patients’ adoption and adherence behaviour mapped on Fogg behaviour model ................................................................. 233
10.5.2 Utility as a support for self-management mapped to the components of the PRISMS taxonomy ................................................................. 238
10.5.3 Potential of technology to support asthma self-management .......... 244
10.5.4 Legislation: a barrier versus necessary safety regulation .................. 249

Chapter 11 Implications ........................................................................ 250

11.1 Implication for healthcare policy ..................................................... 250
11.2 Implications for the NHS

11.3 Implications for the asthma app designer

11.4 Implications for telehealth research

Chapter 12 Conclusions
List of figures

Figure 1 Asthma UK action plan (reproduced with consent) ........................................32
Figure 2 The MRC framework for complex intervention ...........................................36
Figure 3 The Oxford app development road map .......................................................38
Figure 4 General life cycle of healthcare app ..........................................................39
Figure 5 The IT system architecture between NHS, primary care practices and Pharmacy .................................................................................................................41
Figure 6 Illustration of the gap between the requirements of the clinical researchers, technology developer and patients: clinical researchers assessing clinical effectiveness of systems that are out-of-date by the time trials/evaluations are funded and completed; the technology developers seeking maintain patient engagement with frequent ‘updates’ and the patient (and legislators) stuck in the middle with questions about safety. .........................................................................................................................43
Figure 7 Illustration of the inter-related cycles of the framework of the MRC framework and the Oxford app development roadmap ................................................................44
Figure 8 Illustration of the process and outcomes in phase 1 ........................................48
Figure 9 Illustration of the process and outcomes in phase 2 ........................................49
Figure 10 Overview of the three months feasibility study .........................................50
Figure 11 Clinical perspective: illustration of the process and outcomes in phase 1 51
Figure 12 PRISMS flow diagram ...............................................................................57
Figure 13 Risk of bias across intervention ......................................................................65
Figure 14 Forest plot for the meta-analysis of the asthma control and the asthma control outcome of the long term follow up study of Meer .....................................................67
Figure 15 Clinical outcome: asthma control (reproduced with consent[ .................................................................................................................................73
Figure 16 Clinical outcome: quality of life (reproduced with consent[69]) .................74
Figure 17 Clinical outcome: exacerbation ....................................................................74
Figure 18 Patients’ perspectives: illustration of the process and outcomes in phase 1 .......................................................................................................................................................81
Figure 19 Flow chart for the included threads ..............................................................87
Figure 20 The type of forum where the included people were from ..............................89
Figure 21 Respondents’ feedback on features ..............................................................91
Figure 22 Technology/marketing perspective: illustration of the process and outcomes in phase 1 ..........................................................................................................................103
Figure 23 Flow chart for the included app, categorised as ‘self-management app’, ‘asthma tracker app’, ‘peak flow tracker app’, ‘medication tracker app’, ‘general health app’ ..................................................................................................................109
Figure 24 Legislative perspective: illustration of the process and outcomes in phase 1 .........................................................................................................................................................122
Figure 25 Stakeholders’ involvements in the app’s life cycle ........................................123
Figure 26 The process to define the feasibility study .................................................128
Figure 27 Options for data sharing .............................................................................133
Figure 28 Screenshot of the 10 question monitoring ‘motif’ ........................................138
Figure 29 Screenshot of the plan (everyday care) ......................................................139
Figure 30 Screenshot of the plan (worse) ................................................................. 139
Figure 31 Screenshot of the plan (emergency flow chart) ........................................... 140
Figure 32 Overview of the three months feasibility study ............................................ 158
Figure 33 Screenshots of the online consent (left: landing page; middle: information sheet page; right: consent page) ............................................................................................................. 163
Figure 34 Recruitment flow of stream A, B, C and other unknown resources .............. 174
Figure 35 The registration rates from stream A, stream B and stream C .................... 184
Figure 36 Motivations to adopt our app ........................................................................ 188
Figure 37 Adherence rate of the app over time .............................................................. 191
Figure 38 A summary of how participants used the notification and their usage on app .......................................................................................................................................... 192
Figure 39 A summary of what would keep participants to keep using an app and their usage in this study ........................................................................................................... 194
Figure 40 A summary of how participants responded to our digitised action plan and what they think about an asthma action plan ......................................................... 204
Figure 41 Schematic of the features that patients and healthcare professionals wanted to see in telehealth .................................................................................................................. 223
List of tables

Table 1 Recommended outcome measures relating to asthma control for clinical trials: list of measures (ATS guidelines: table 2) ................................................................. 28
Table 2 The 14 components to support patients with long term conditions and their descriptions ........................................................................................................... 31
Table 3 The four different perspectives to explore the feasibility .................................. 46
Table 4 Definition in this systematic review, search strategy and reasons for these choices ................................................................. ................................................ 53
Table 5 Clinical outcomes of the included interventions ................................................ 58
Table 6 Application features of the included interventions (reproduced with consent[69]) .... 70
Table 7 Summary of adoption and adherence of the intervention ..................................... 76
Table 8 Search strategy .................................................................................................. 84
Table 9 Titles of threads ................................................................................................ 88
Table 10 Features and people’s feeling on the existing app or smart device or social media ................................................................. 94
Table 11 Search strategy ................................................................................................ 106
Table 12 summary of app’s features and their numbers of downloads on 07/04/2016 and 11/04/2017 .................................................................................................................. 109
Table 13 The 14 PRISMS taxonomy components and the features extracted from the existing apps on Apple and Android stores .................................................. 118
Table 14 Screenshots of the features .............................................................................. 141
Table 15 Description of the features ............................................................................. 142
Table 16 Comparison between Fogg behaviour model, COM-B and PRIME ................. 149
Table 17 Inclusion criteria, exclusion criteria and purposive sample criteria ............... 151
Table 18 Leading questions related to the core elements in behaviour change model .... 165
Table 19 The four quantitative data collections methods mapped to the outcome measurements and objectives ................................................................. 169
Table 20 Age and gender of patient participants ............................................................ 176
Table 21 Purposive sampling matrix of the participants who took part in our interviews ................................................................................................................................. 179
Table 22 Practice characteristics ................................................................................... 180
Table 23 Summary of participant’s responses on what made them decide to download an app to support their self-management .................................................. 184
Table 24 Numbers of patients who showed their interest in the app during the nurse consultation ..................................................................................................................... 186
Table 25 Adherence of the app from different steams ..................................................... 191
Table 26 The participants’ responses on what would they like to see in an app to support their self-management (Note: shaded are the ‘baseline’ features that more than 50% of participants in the initial questionnaire supported. Features which had over 90% supports are highlighted in bold.) ............................................................................... 198
Table 27 A summary of the features used by participants .............................................. 200
Table 28 The numbers of participants who used an action plan on the app and their ownership of paper based action plans ...................................................... 201
Table 29 Influence of motivation, ability and triggers on adoption mapped to Fogg behaviour model ......................................................................................... 235
Table 30 Influence of motivation, ability and triggers on adherence mapped to Fogg behaviour model ..................................................................................... 237
Table 31 Summary table of PRISMS and application features ........................................ 239
Table 32 Conclusions from the four perspectives .......................................................... 258
Appendices

Appendix 1 NHS Lothian asthma self-management plan
Appendix 2 Published systematic review in JAMIA
Appendix 3 Search strategy of the nine databases
Appendix 4 Supplementary appendix of the published systematic review in JAMIA
Appendix 5 Short paper (in press) in BCS HIS conference proceedings
Appendix 6 MARS scoring questions
Appendix 7 MARS score
Appendix 8 10 motif questions and thresholds
Appendix 9 The system architecture of our app prototype
Appendix 10 GRAMMS checklist
Appendix 11 REC and HRA approvals
Appendix 12 Nurse recruitment pack
Appendix 13 Study protocol, IRAS form, recruitment packs and A4A webpage
Appendix 14 Online consent process
Appendix 15 Topic guide for patients and practices in stream A
Appendix 16 Pre study questionnaire
Appendix 17 Post study questionnaire
Appendix 18 Enquires or feedback from the app enquiry box/emails
Appendix 19 A4A discussion forum
Appendix 20 Advertisements/feedback from Facebook and Twitter
Appendix 21 Practices’ feedback on memo
Appendix 22 Coding summary
Appendix 23 CASP checklist
Appendix 24 Risk assessment for asthma self-management apps
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Contributions to science

Publications and Presentations

Peer-reviewed publications


Abstracts


8. Poster: Developing, Refining and Piloting Integrated IT Application with adoptive and adherent features to support Asthma Self-Management. June


Abbreviations

ACQ: Asthma Control Questionnaire
ACT: Asthma Test
ATAQ: Asthma Treatment Assessment Questionnaire
A&E: Accident And Emergency Departments
AUKCAR: Asthma UK for Applied Research
BSI COP/PAS: British Standards Institution Code of Practice/ Publicly Available Specification
BTS/SIGN: British Thoracic Society/ Scottish Intercollegiate Guidelines Network
CASP: Critical Appraisals Skills Programme
COP: Code of Practice
CRD: Centre for Reviews and Dissemination
EHR: Electronic Health Records
EPS: Electronic Prescription Service
EPOC: Effectiveness and Practice Organisation of Care
ER: Emergency Room
ERS: European Respiratory Society
FeNO: Exhaled Nitric Oxide
FEV1: Forced Expiratory Volume
FVC: Forced Vital Capacity
GINA: Global Initiative for Asthma
GP: General Practitioner
GPSoC: GP Systems of Choice
GRAMMS: Mixed Methods Study Guideline
HRA: Health Research Authority
ICT: Information And Communication Technology
ICS: Inhaled Corticosteroid
IOM: Institute of Medicine
IT: Information Technology
ITU: International Telecommunication Union
IMP²ART: Implementing Improved Asthma self-management as Routine Treatment
JAMIA: Journal of the American Medical Informatics Association
KASE-AQ: Knowledge, Attitude and Self-efficacy Asthma Questionnaire
LABA: Long-acting beta-agonist
LTCs: Long Term Conditions
MARS: Mobile App Rating Scale
MHRA: Medicines and Healthcare products Regulatory Agency
Mini AQLQ: Mini Asthma Quality Of Life Questionnaire
MRC: Medical Research Council
NHS: National Health Service
NFC: Near Field Communication
OCS: Oral Corticosteroids
PAQLQ: Paediatric Asthma Quality Of Life Questionnaire
PCAQ-6: Perceived Control of Asthma Questionnaire  
PCRS: Primary Care Respiratory Society  
PDS: Personal Demographics Service  
PEF: Peak Expiratory Flow  
PICOS: Population, Intervention, Comparison, Outcome and setting  
PRISMS: Practical Reviews in Self-Management Support  
QoL: Quality of Life  
RCT: Randomised Controlled Trial  
RCP3Qs: Royal College of Physicians Three Questions  
SCR: Summary Care Records  
SMS: Short Message Service  
STU: Scottish Therapeutics Utility  
WHO: World Health Organization  

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DR: Dermot Ryan  
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Glossary

**Digital health.** The use of wearable and implantable technology, web and email, mobile technology and social networking, and data management and analytics to improve health. It encompasses many sectors including telehealth, telemedicine, ehealth and mhealth[1,2].

**Telehealth.** The use of telecommunications and virtual technology to deliver health care outside of traditional health-care facilities. It encompasses a broader definition of remote healthcare that does not always involve clinical services[3,4].

**Telemedicine/Telecare.** The use of telecommunication and information technologies to deliver clinical services[1].

**ehealth.** The use of computers to deliver healthcare services[5].

**mhealth.** The use of mobile devices to deliver healthcare services[6].

**Digital health intervention.** The use of digital technologies, with or on behalf of a person or population whose purpose is to assess, improve, maintain, promote or modify health, functioning or health conditions[7].

**Adoption.** Download an app or starting to use the telehealth

**Adherence.** Involving continued use of an app or a telehealth, not necessarily every day but when needed, informed by a sense that an app is something to help each patient in their asthma self-management journey.

**Engagement.** Adoption and adherence to use an app or a telehealth. (Also see Adoption and Adherence).

**Retention.** People who are not giving up the use of an app or a telehealth.

**Follow up.** A further action connected with the previous actions.
Chapter 1  Introduction

1.1.  Current understanding of asthma

1.1.1.  What is asthma?

Asthma is a chronic disease and one of the most common long term conditions. The Global Initiative for Asthma (GINA) defined asthma as “a heterogeneous disease, usually characterized by chronic airway inflammation. It is defined by the history of respiratory symptoms such as wheeze, shortness of breath, chest tightness and cough that vary over time and in intensity, together with variable expiratory airflow limitation”[8]. The World Health Organization (WHO) estimates that 235 million people currently suffer from asthma worldwide[9], while almost 4.3 million adults suffer from asthma in the UK[10]. The symptoms of asthma, as cited above, are wheezing, breathlessness and coughing, the severity of which varies from time to time. The causes of these symptoms are airway inflammation, leading to bronchoconstriction (airway narrowing), thickened airway wall, increased of mucus[8] and also smooth muscle hypertrophy which increases the airway narrowing[11]. Extrinsic (allergic) asthma is often triggered by allergens such as pollen, animal feathers, mould, indoor and outdoor air pollutants; intrinsic (non-allergic) asthma is often triggered by non-allergic factors such as cold air, exercise and emotional upset[12].

1.1.2.  The history of asthma

A written treatment for a condition with symptoms like asthma, was found in ancient Egypt and China from about 1550 B.C. and 1000 B.C. respectively – Ebers Papyrus in Egypt, suggested remedies with herbs, enemas and the administration of animal excrement; while in China, Huangdi Neijing (黃帝內經) suggested remedies with herbs, including Ma Huang that contain ephedrine, which is chemically related to the drugs in modern beta2 agonist inhalers[13,14]. The Huangdi Neijing used three basic theories to decide the combinations of herbs and make up the remedies. Those theories were: i) ‘Yin-Yang’, which was the core of the chines medical physiology, pathology and treatment; ii) the ‘five elements’, represented by water, fire, wood, metal, earth and iii) the ‘Qi’, meaning ‘breathe’ of the patient[15]. Asthma (어마) was firstly used as a medical term in the Corpus Hippocratic in the 4th century B.C.
and is derived from the Greek verb ἀσπάσθαι (aazein), meaning to pant, exhale with the open mouth and ἀπειροῖν meaning to blow[16,17,18]. In the 1st century A.D., Aretaeus of Cappadocia, wrote the first clinical description of asthma, he described the symptoms as “heaviness of the chest... difficulty of breathing in running or on a steep road; they are hoarse and troubled with cough…”[19]. Later in 1860, Henry Hyde Salter provided evidence to suggest asthma was a nervous disease, stating that the cause of asthma was "perverted nervous action". Therefore, he was adamant that "Sleep favours asthma." and advocated hot strong coffee to control the asthmatic attack[20]. However, Salter’s theory was disproved by William Budd and Alton Wintrich, a rejection verified by Guillaume Benjamin Amand Duchenne[21].

Whereas, in traditional Chinese medicine, Mai-men-dong-tang (a 5-herb formula) and Ding-chuan-tang (a 9-herb formula) were used for asthma remedies, supported by evidence with respect to improving the asthma symptoms of children between 5-18[22]. Also, there were other supplements (for example, wild cordyceps and gecko) that some patients would take routinely to prevent exacerbations of their symptoms. However, there was no significant evidence to prove the effectiveness of these supplements on asthma.

Today, asthma is known as an inflammatory airway disorder. It has also become increasingly clear that there is a relationship between asthma, rhinitis, and eczema[14]. A more precise definition and classification of asthma, improved diagnostic methodologies and a stepwise treatment approach have been established and systematically guided by the GINA and British Thoracic Society/Scottish Intercollegiate Guidelines Network (BTS/SIGN)[8, 24]. A recent publication by the Lancet summarised the commission recommendations for the next 25 years. They suggested a redefinition of asthma, “the current physiology-based classification system for airways diseases is outdated...there is a need to be clear about the meaning of those current labels for asthma and acknowledge the assumptions associated with them” in order “to begin a new era of examining, monitoring, treating and preventing asthma”. The aim of this change is to further reduce the hospital admissions and mortality rates currently associated with asthma. The Lancet suggested ‘It is unacceptable that people still die from asthma attacks in 2017’[23].
1.1.3. Pharmacological management of asthma

There is no cure for asthma but it can be controlled by medications. The medications are generally delivered by inhaler; a procedure which has the advantage of potentially getting the optimum dose directly to the lungs, thereby reducing the amount of medication that gets into the patient’s general circulation. However, these treatment chemicals may cause side effects and are difficult to use; therefore, patients need to be taught the correct inhaler technique. There are three main categories of medications for asthma: a) controller/preventer medications such as inhaled corticosteroids, which should be used regularly to control symptoms, reduce airway inflammation and reduce future risks of exacerbation b) reliever /rescue medications such as “blue” inhaler in the UK, which is used in a sudden breakthrough of symptoms to quickly relax breathing tubes; c) add-on therapies, a combination of controller and reliever, which is used for people with severe asthma, persistent symptoms and/or exacerbation[8].

1.2. Support for self-management

1.2.1. Definitions and outcomes

Apart from pharmacological treatments, there is strong evidence that self-management with a personalised asthma action plan can reduce emergency use of healthcare resources, improve asthma outcomes and reduce morbidity[24,25,26,27]. There are several different definitions of self-management. However, the US Institute of Medicine (IOM) has provided a definition which has summarised the common themes emerging from those definitions. The IOM defined self-management as “…the tasks that individuals must undertake to live well with one or more chronic conditions. These tasks include having the confidence to deal with medical management, role management and emotional management of their conditions”[28]. This definition highlights that self-management is a ‘task’ for patients (implies an ‘action from patients’) in order for patients to ‘live well’ with their chronic conditions. Confidence (or self-efficacy) is needed to perform these tasks. The ‘task’ includes three components: i) medical management, ii) role management and iii) emotional management of their chronic conditions.

There is another concept which is similar to ‘self-management’; that of ‘self-care’. ‘Self-care’ is a broader concept adjacent to ‘self-management’. ‘Self-care’ is defined
as “individual responsibilities for healthy lifestyle behaviours required for human development and functioning”[29]. ‘Self-care’ is more general than ‘self-management’ and addresses macro lifestyle rather than more micro disease specific issues. ‘Self-care’ also stresses that taking actions is the patient’s ‘responsibility’ which implies the patient is the centre of self-management. In other words, the patient’s active engagement in the organisation of their lives and conditions is crucial to the performance of successful self-management. The norm behind self-management is for the patient to be aware of their asthma and so they would know what to do when their asthma was getting worse, and be competent enough to do it.

To measure outcomes of any asthma treatments, the ATS guidelines[30] recommend the asthma control questionnaire (ACQ), asthma control test (ACT), measures of quality of life (QoL), medication adherence, number of emergency room(ER) visits and unscheduled GP consultations. Table 1 shows the list of recommended tools.

Table 1 Recommended outcome measures relating to asthma control for clinical trials: list of measures (ATS guidelines: table 2)

<table>
<thead>
<tr>
<th>Essential</th>
<th>Desirable</th>
<th>Optional</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Baseline characteristics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Symptom-free days; Reliever use; Pre-BD forced expiratory volume (Pre-BD FEV1); Post-BD forced expiratory volume (Post-BD FEV1); Composite scores, at least one, and preferably two, validated composite measures (e.g., asthma control questionnaire, ACQ), asthma treatment assessment questionnaire (ATAQ), asthma control test (ACT)) should be recorded; Quality of life (QoL)</td>
<td>Symptom/reliever/lung function diary; Airway hyperresponsiveness; Biomarkers; Treatment side-effects; History of exacerbations (oral corticosteroids (OCS), emergency room visits (ER visits), hospitalizations)</td>
<td>On-treatment forced expiratory volume (On-treatment FEV1)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>2. Outcome measures for the assessment of treatment effect</strong></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>On current clinical control</strong></td>
<td>On-treatment FEV1; Symptom/reliever/lung function diary; Indirect measures, e.g., corticosteroid use, health care utilization</td>
<td>Biomarkers; Airway hyperresponsiveness; Post-BD FEV1</td>
</tr>
<tr>
<td>Symptom-free days; Reliever use; Composite scores; Exacerbation (within last 1-4 wk); Quality of life</td>
<td>For direct measurement of adverse outcomes: • Exacerbations; Post-BD FEV1 (for assessment of lung function decline); Composite scores; Treatment side-effects</td>
<td>For direct measurement of adverse outcomes: • Symptom/reliever/lung function diary; Health care utilization (e.g., corticosteroid use, ER visits, hospitalizations); mortality due to asthma</td>
</tr>
<tr>
<td>For indirect assessment of risk of adverse outcomes: • Pre-BD FEV1 (as predictor for exacerbations)</td>
<td>For indirect assessment of risk of adverse outcomes: • Airway hyperresponsiveness (as predictor of future risk)</td>
<td>For indirect assessment of risk of adverse outcomes: • Biomarkers (as predictor of future risk)</td>
</tr>
</tbody>
</table>
To evaluate the intermediate outcomes of the self-management interventions, many studies measured a patient’s ‘self-efficacy’[31]. ‘Self-efficacy’ is a behavioural concept that encompass patients’ beliefs in their abilities to perform self-management; the concept has been defined as ‘the individual’s belief in their capacity successfully to learn and perform a specific behaviour’[32]. This concept helps us to understand if the patient participant has self-confidence to perform self-managing tasks; however, the concept is not helpful to determine the likelihoods that patients would translate their beliefs into actions. A similar, but related concept is ‘patient activation’, defined as ‘knowledge, skills and confidence a person has in managing their own health and health care’[33], which has been adopted for use in the UK NHS. There are four levels in the measurements of the concept. A higher level of activation predicts a better intermediate outcome of the intervention. Compared to ‘self-efficacy’, ‘patient activation’ is a broader concept that is more relevant to clinical practice. The latter not only includes ‘confidence’, which is the core component of ‘self-efficacy’, but also includes the additional parameters of knowledge and skills. Knowledge and skills are the more practical components needed for the implementation of self-management in practice. For example, a patient could be very confident on performing self-management, however, without appropriate knowledge and skills he or she may get things very wrong.

Though the patient is the centre of self-management, adequate support from clinical practices and their health carers is needed[24]. Self-management support for chronic conditions ‘is the assistance that professional and informal caregivers give patients with chronic disease in order to enable them to take decisions about their condition and to manage disease and health-related tasks[31]’. For asthma patients, the key aspects of support are to provide structured education and to reinforce their knowledge through discussion with an asthma action plan. The practical supporting tasks are for example, to check the patient’s peak flow and inhaler technique and to provide a written action plan[24]. The norm of these supportive initiatives is to form a partnership with each patient, to provide assistance when he or she needs it during their management journey as opposed to developing a dependence on the practice or carers to monitor their asthma.
1.2.2. Self-management support for long term conditions

The concept of self-management also applies to other long term conditions. A recent practical review in self-management support (PRISMS) examined the previous self-management interventions for different long term conditions. The review derived a taxonomy of 14 components that healthcare organisations should consider when they are planning to support patients with long term conditions (LTCs)[34]. Table 2, in the following page, shows these components. They include, for example, provision of information about their condition or management, provision of clinical action plan, provision of equipment and easy access to support and training to communicate efficiently with healthcare professionals and social support. These 14 components will not all be relevant to all long-term conditions, and will not apply to all individuals with a long-term condition; the taxonomy is described as a ‘pick-list’ not a ‘check-list’. It is, therefore, helpful to in use as a framework to review what technologies can contribute to support self-management in a broader sense. Therefore, I decided to use these 14 components to synthesise my findings, which I will discuss in detail in the ‘methods’ section of each review and study.
Table 2 The 14 components to support patients with long term conditions and their descriptions (Reproduced with consent[34]).

<table>
<thead>
<tr>
<th>Taxonomy item</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>A. Information about condition and/or its management</td>
<td>Providing people with LTCs with information and instruction about their LTC or about general aspects and principles of managing their LTC (physiology, medication, prognosis, emotional, psychosocial, etc.)</td>
</tr>
<tr>
<td>B. Information about available resources</td>
<td>Providing people with LTCs with information (e.g., written, verbal, visual) on issues such as financial benefits, sources of social or peer support, charitable organisations.</td>
</tr>
<tr>
<td>C. Provision of agreement on specific clinical action plans and/or rescue medication</td>
<td>Written instructions prepared with, or by, a healthcare professional to enable the person to stay in control of their condition, tailored to the person, LTC, and severity. Includes how to take medication, how to recognise symptoms of deterioration and what actions to take.</td>
</tr>
<tr>
<td>D. Regular clinical review</td>
<td>A regular, scheduled review of the person, their condition and self-management, conducted by a healthcare professional</td>
</tr>
<tr>
<td>E. Monitoring of condition with feedback</td>
<td>Monitoring symptoms, behaviours or objective measures related to LTC. Can be done by the person with an LTC or by others, but the results must be fed back to the patient. Interpretation, decision and/or action is undertaken by the patient, LTC, and severity. Includes how to take medication, how to recognise symptoms of deterioration and what actions to take.</td>
</tr>
<tr>
<td>F. Practical support with adherence (medication or behavioural)</td>
<td>Provision of practical help to improve a person’s adherence to medication or behaviour change activities.</td>
</tr>
<tr>
<td>G. Provision of equipment</td>
<td>Provision of equipment to enable, assist or promote self-monitoring and/or self-management of the LTC.</td>
</tr>
<tr>
<td>H. Provision of easy access to advice or support when needed</td>
<td>People with LTCs are provided with flexible access to, and timely advice from, health services in the event of an urgent or non-urgent question or concern arising.</td>
</tr>
<tr>
<td>I. Training/rehearsal to communicate with healthcare professionals</td>
<td>Teaching people with LTCs to develop communication skills/techniques to improve relationships, better communicate their needs, and enhance shared decision making with healthcare professionals. Also supporting/mentoring people with LTCs to practise the skills they have been taught.</td>
</tr>
<tr>
<td>J. Training/rehearsal for everyday activities</td>
<td>Teaching people with LTCs to develop skills that support everyday activities and/or supporting people with LTCs to practise the skills they have been taught.</td>
</tr>
<tr>
<td>K. Training/rehearsal for practical self-management activities</td>
<td>Teaching people with LTCs to develop specific practical skills that will enable them to manage their LTC, and/or supporting people with LTCs to practise the skills they have been taught.</td>
</tr>
<tr>
<td>L. Training/rehearsal for psychological strategies</td>
<td>Teaching people with LTCs skills in using psychological strategies to help them better manage the consequences of an LTC and/or supporting them to practice the skills they have been taught. May include: problem-solving strategies, relaxation techniques, reframing, distraction, cognitive restructuring, goal setting and action planning (prompts detailed planning of performance of the behaviour/outcome of the behaviour; NB this does not have to be health behaviour focused).</td>
</tr>
<tr>
<td>M. Social support</td>
<td>Facilitation of social support, where a person feels cared for and supported by others in a social network. May include befriending, peer support, peer mentoring and group socialising.</td>
</tr>
<tr>
<td>N. Lifestyle advice and support</td>
<td>Provision of advice and support around health and lifestyle. Relates to practical advice and support in relation to handling life stressors, NOT psychological elements that relate to handling life stressors (see training/rehearsal in psychological strategies). May include general lifestyle advice and support concerning diet, physical activity, smoking cessation, and controlling alcohol intake.</td>
</tr>
</tbody>
</table>
1.3. Supported self-management with a personalised asthma action plan improves asthma outcomes

Having discussed the components of self-management, and self-management support for asthma patients, as well as other long term conditions, I will now explore the issue of effective self-management support to patients with asthma.

A personalised asthma action plan is the core element amongst those self-management interventions that result in improved asthma outcomes[24]. The BTS/SIGN guidelines suggest that, together with the action plan, knowledge about asthma and regular discussions with healthcare professionals about asthma are also needed for a better asthma outcome[24]. Therefore, the core components for effective self-management support are to provide a structured education to strengthen the patient’s knowledge with an asthma action plan.

1.3.1. What is an asthma action plan?

Figure 1 Asthma UK action plan (reproduced with consent)

A personalised asthma action plan (see example in Figure 1) is a set of tailor-made self-management instructions or actions for a patient to take or follow in the event of deteriorating asthma. It informs the patient i) how to recognise that their asthma is deteriorating, ii) when and how to modify medications, and iii) when and how to...
access medical advice[35]. The plan is also a tool to encourage discussion between the healthcare professionals and patients to work out a ‘tailor-made’ management strategy in the routine consultation. ‘Tailor-made’ here means that the healthcare professionals can enter the patient’s best peak flow and the appropriate medications on a standardised form. An effective action plan could be based on symptoms or personal best peak flow data, using two to three action points to trigger self-management decisions[24].

For adults, there are two commonly used action plan templates in the UK and Lothian: i) the Asthma UK action plan[36] (see Figure 1) and ii) the NHS Lothian self-management plan[37] (see Appendix 1). Both of them are freely available for anyone to download and can be accessed via the electronic health record used in many UK and Lothian practices. These plans use intake of medication, symptoms and peak flow values as triggers to determine the asthma state. The asthma states are divided into three zones– ‘green zone for well controlled’, ‘amber zone for getting worse,’ and ‘red zone for emergency’. The differences between the two plans cited above are their design and the advice regarding the emergency condition– Asthma UK[36] suggests a flow chart for decision making whereas the NHS Lothian[37] provides advice set out in three bullet points.

1.4. The problem: Implementation of self-management remains poor

Unfortunately the implementation of self-management plans remains low, despite the overwhelming evidence that self-management with an action plan improves an asthma patient’s asthma outcomes. According to Asthma UK’s ‘Time to take action on asthma, 2014’ report, 70% of asthma patients did not have an action plan[25]. Such poor ownership suggests that there must be some barriers in clinical practice to discourage or hinder the usage of an action plan in clinical practice. Previous researchers have identified those barriers – they are a) practical, b) conceptual and c) organisational. Practical barriers include lack of time and resources, and no immediately available paper-based asthma action plan[38]. Conceptual barriers include a mismatch between the advice from professionals and the advice patients want for living with their asthma[39]. Organisational barriers include the lack of flexible systems for facilitating effective communication between professionals and patients[40].
The implementation rate of asthma self-management, in general, refers to each of the three measurable markers, they are i) ‘provisions of action plan’, ii) ‘ownership of action plan’ and iii) ‘use of action plan’. ‘Provision of action plans’ is measurable from a clinician’s perspective; they give patients action plans and this provision should be measured by entries in the patient’s clinical record. ‘Ownership of action plans’ refers to whether the patients have an action plan, which they may have been given but consequently lost. This ownership issue could be measured by asking the patient whether they currently have a plan. ‘Use of action plans’ implies ownership of a plan and actually using it; a condition which is typically measured by asking the patient about plan ownership. Any of the above three markers can be used as an outcome measurement, but they are measuring different things. Therefore, they cannot necessarily be compared.

1.5. Telehealth is a potential solution for the problem

Nowadays, the mobile smartphone is being increasingly adopted and used worldwide[41]. Mobile applications (apps) are widely used by people with asthma for health management[42,43]. In 2013, there were 191 apps written in English for people with asthma, readily available to download[44] and the Apple app store[44,144]. App technology is flexible. In addition to providing a handy way to store an asthma action plan, an app can also provide educational videos, medical reminders, symptom-logging features, as well as facilitating online consultations for asthma patients. It is possible to integrate different features in one app and allow customisation of features in a single app. Such an option can reduce some of the adoption barriers that were mentioned in the section 1.4 above. Therefore, technology such as a smartphone app, has the potential to be an initiative to encourage patients to own an action plan and to provide additional support for that patient’s self-management. A recent BTS/SIGN guideline provided evidence that echoed this view (BTS/SIGN guideline section 14.4.1[24]). From a technology perspective, it is relatively easy to develop an app; learning resources such as tutorials, software toolkits and example programming codes are free to download online and there are hundreds of asthma apps available[44, 45]. However, to develop an app that fulfils the features of self-management support and that will be used, requires a good understanding of the clinical, patient and legislative perspectives. For example, we need to understand what self-management support that patient
would like to see? What self-management support that a healthcare organisation can offer and what healthcare professionals think about apps. In addition we need to know what technology can deliver in the way of support and how legislative directives[46,47, 48] affect the development of self-management apps.

1.6. The patients’ perspective

Attracting downloading, as well as encouraging an on-going engagement with apps is challenging[49]. Firstly, there are more than 400 asthma apps in the market[50]; it is therefore extremely challenging to persuade patients to choose a particular app, as they are unsure about which app should be chosen and how could an app can particular help with their asthma[51, 52]. Secondly, many users open an app only once after downloading it and then never go back. Thirdly, users frequently download an app, use it for a short while but typically stop using it within 30 days[53].

The issue of non-adherence to an app-based plan is therefore a problem. Triggering features which speak to their ‘wants’ as opposed to asking them to use an app designed by clinicians, which may not meet their perceived needs, may be one way to increase engagement. Therefore, the next question is what are the app features that patients are looking for to support their asthma self-management? In general, healthcare apps with features that saved time and provided a more efficient way of managing care than the current one, are wanted by users and are more likely to promote usage[54]. However, in the specific context of asthma self-management, the features users want remains unknown. Therefore, I decided to find these out in this research.

1.6.1. Exploring features that asthma patients want in an app, in order to support their self-management

When trying to determine the features that patients wanted, I looked at each patient’s engagement with the app, which I divided into two parts: i) adoption (downloading an app) and ii) adherence, which involves continued use of an app, not necessarily every day but when needed, informed by a sense that an app is something to help each patient in their asthma self-management journey. In this study the features that attract adoption, I have called ‘attractive features’; while the features that encourage adherence I call ‘adherent features’.
Adoption can be measured by the numbers of downloads of an app, but attractive features are identified from patients’ opinions. Adherence is not a simple measurable parameter; it needs to be explored by speaking with the patients and healthcare professionals. Healthcare professionals are also needed because they play a key role to support patient’s self-management. Therefore:

- In phase 1 (chapter 3-6), along with a literature review, I collected patients’ views from online discussion forums and app stores.
- In phase 2 (chapter 7), I spoke to patients and professional advisory groups to inform the design of the study, the questions to be asked in the later interviews and the app prototype designs.
- In phase 3 (chapter 8-10), I then recruited patients to use my app prototype via different media – Facebook, Twitter, healthcare practice invitation letter and nurse in person invitation during consultation; patients and healthcare professionals were interviewed in order to explore their thoughts on the features that they wanted to see.

1.7. The healthcare service and professionals’ perspective

From a healthcare perspective, to choose appropriate methods to develop, design, evaluate and implement a complex interventions, researchers use the MRC framework[55] (See Figure 2, used with the permission of the Medical Research Council).

![Figure 2 The MRC framework for complex intervention](image)

There are four stages in the framework. They are: i) the development stage, ii) the feasibility/piloting stage, iii) the evaluation stage and iv) the implementation stage. The stages are not in a linear or cyclical sequence, meaning a decision made in one
stage would interact with decisions with the previous or next stages. Three main points are suggested in each stage to help researchers to think about which methodologies are best for their intervention. The development stage suggests researchers identify evidence to define their intervention and think about what outcomes about the intervention they would like to measure. The feasibility/piloting stage suggests researchers think about how pragmatic their interventions are. The evaluation stage suggests tests to assess the intervention effectiveness. The randomised controlled trial (RCT) is the central part of the evaluation because this methodology eliminates as far as possible the confounding variables in order to establish effectiveness and safety. Guideline recommendations are based primarily on the RCT evidence which, in the BTS/SIGN guidelines[24] define the level of evidence and grades of recommendation. The implementation stage suggests approaches to translate the findings into routine practice or policy. There are no fixed timelines for each stage – and completing this process is likely to take a decade. Timelines for acquiring funding, and achieving ethics and governance approvals, are confounded in telehealth interventions, if it is classified as a medical device. With such an outcome more time is needed to apply for the approvals from the UK Medicines & Healthcare products Regulatory Agency (MHRA) before asking participants to try out the prototype.
1.8. The technology developers’ perspective

1.8.1. The ehealth app development road map

The Oxford road map[56] suggests key considerations to develop, design, evaluate and implement a healthcare app (See Figure 3, reproduced with consent[56]).

![Figure 3 The Oxford app development road map](image)

Similar to the MRC framework, there are six stages in the roadmap. They are i) pre-development, ii) design & development, iii) user testing, iv) stakeholder review/clinical validation, v) medical device process and vi) external deployment. The pre-development stage suggests developers should assess if the app is worthy of development from a business point of view; for example ‘what are the user profiles?’, ‘where is the funding to develop the app?’ and ‘what is the value of the app?’. In the design and development stage, the Oxford roadmap[56] suggests the key considerations about the technical issues are the user requirements, coding generation, user interface design, system interoperability and capability. The user testing stage suggests the app developer invite potential users to access the prototype and provides comments. This is usually an iterative process before refining a final prototype. When the final prototype is ready, the next stage is the stakeholder review or clinical validation. In this stage stakeholders are asked to review the performance of the prototype. If the prototype is a part of a telehealth intervention, this is the stage at which its clinical effectiveness is assessed. The last two stages are ‘medical device process’ and ‘external deployment’. If the prototype is developed for a
commercial market, this stage is the time to consider the registering the prototype with the CE marks and applying for other necessary approvals under the medical device directives\[46,47,48\]. After that, it is the time to think of the advertising of the prototype and the appropriate app stores to launch the prototype. After that, it is time to think of the advertising of the prototype and the appropriate app stores from which to launch the prototype. The key difference from the MRC framework is that the Oxford road map involves no RCT, which is regrettable since the RCT is necessary to healthcare systems for establishing effectiveness and safety.

1.8.2. Typical lifecycle of a healthcare app

![Diagram of the lifecycle of a healthcare app](image)

Key: Path 1-4 Illustration of the iterative revision cycle in practice

Figure 4 General life cycle of healthcare app

The healthcare app landscape is rapidly changing. The British Standards Institution Code of Practice/ Publicly Available Specification 277:2015 (BSI COP/PAS 277:2015)[57] provides a general life cycle of typical healthcare app. PAS 277 COP aims to provide a set of practical principles for healthcare app developers to follow in the UK in order to develop high quality and trustworthy healthcare apps[57]. The general lifecycle suggested in this COP was similar to the Oxford app’s development
roadmap[56] but the description was more technically specific for app developers. The general life cycle was divided into eight stages: i) planning, ii) requirement analysis and research, iii) design, iv) application testing, v) implementation, vi) release, vii) maintenance and viii) discontinuation of app project life cycle (see Figure 4). PAS 277 COP starts from brainstorming the app to designing the code, features and interface based on a series of researches and analysis cycles, and then passes through different code and user testing to make sure the ideas work in the app before its implementation. Lastly, the developer releases the app onto the app market and maintains it over time until the app is removed from that market. However, in practice, the cycle is a parallel rapid cycle between the application testing stage and the maintenance stage. The latter stage includes reviewing users’ feedback, amending codes (Figure 4, red line, path 1-2), testing and debugging, implementing changes and releasing again as a revised version (Figure 4, blue line, path 3-4). This process aims to enhance the app’s features and correct any bugs in order to attract and keep more users in the competitive app’s market. Therefore, to be realistic, the development and refining process of my app prototype would use an iterative ‘parallel’ approach; meaning that the app will be revised after collecting comments from patients.

1.8.3. The NHS context: IT architecture between NHS, primary care practices and pharmacy

In order to choose the appropriate design for the app prototype, it was important to understand how the data flows between NHS, primary care, practice and pharmacy. There are four principle system suppliers to provide the IT products and services to practices. Those are TPP SystmOne, EMIS Web, InPS Vision and Microtest Evolution[58]. These services provide a platform for primary care practices to manage their usual daily care workload and are granted permission to access the NHS principle clinical systems such as Electronic Prescription Service(EPS), GP2GP, the NHS e-Referral Service, the Personal Demographics Service(PDS) and Summary Care Records(SCR), through the spine’s backbone. The EPS allows prescriptions to be sent to pharmacies from the practice’s IT system[59]. This option allows the connections with pharmacies to provide direct or repeat ordering of medications to a patient’s home. Pharmacy2u and Boots are the examples of outlets providing these services to patients. GP2GP allows patients’ data to be transferred
from an old practice to a new healthcare practice when patients change practices[60]. The NHS e-Referral Service allows referral booking in hospital or practice[61]. The PDS is a national database of NHS demographic information such as name, address, date of birth and NHS Number[62]. The SCR is the database of a summary of each patient’s medical record[63]. The structured clinical vocabulary, SNOMED CT, is intended to be used to code the enquiry for extracting information from the database[64]. The system’s architecture is illustrated in Figure 5.

![System Architecture Diagram](image)

Figure 5 The IT system architecture between NHS, primary care practices and Pharmacy

1.9. The legislative perspective

From the legislative perspective, there are no European Union (EU) regulations for standalone apps but most EU States use the directives of MDD 93/42/EEC[46], AMID 90/385/EEC[47] and IVD 98/78/EEC[48], as well as having their national legislation which they apply to standalone apps. The definition of ‘medical device’ in the directive MDD 93/42/EEC[46] and Medicines & Healthcare products Regulatory Agency (MHRA) guidelines[65] classifies many standalone healthcare apps as ‘medical devices’, thus including most of the asthma self-management apps in the regulatory pathway. As an asthma action plan forms the core features of a self-management app, which advises a patient on the actions to take when their asthma deteriorates, the app will always be considered as a ‘medical device’. The regulation of health apps is important to protect user’s safety and privacy. However, an over-
zealous approach to regulation not only slows down app development, stifles innovation to the detriment of economic prosperity but also overloads regulatory examiners, such as those from the MHRA. Indeed, the difficulties of carrying out app development under the current legal framework has provoked considerable discussion in a joint stakeholders meeting hosted by the Royal Academy of Engineering and the Academy of the Medical Sciences. The difficulties highlighted included: a) the complexity of current regulations, b) the suitability of current legal framework, c) vigilance and monitoring issues, d) obstacles to app use and promoting app uptake, e) generating and evaluating the evidence of clinical utility, f) the role of app’s stores and g) the necessary software development practices under the frameworks. In conclusion, risk aversion and specifically, failure to differentiate and thus handle differently high and low risk interventions, is the root cause behind an over-zealous approach.

1.10. The clinical, patient, technology and legislative perspective on telehealth

Different stakeholders have different perspectives on telehealth. Safety is the prime consideration from the clinical perspective. Undoubtedly, safety and patient engagement are both important for telehealth. That is simply because we cannot advise patients to use a technology which increases risk and may endanger their lives. Similarly, a telehealth app which shows promising health benefits, but which is not adopted by patients will not improve any patient’s health. Therefore, for any technology telehealth interventions, reviewing clinical effectiveness of past telehealth interventions, synthesising existing evidence is always the first step before developing and refining a telehealth intervention[55]. In contrast, from the technology developer’s perspective, engaging patients to use technologies is the prime consideration. The developers are interested in how to encourage patients to adopt and keep using their technologies; looking for attractive and adherent features to develop technologies in the future. From the patients’ perspectives, they are exposed to many advertisements about healthcare products every day. Most of these products claim that they can ‘help’ to manage their asthma but lack any significant clinical evidence about the health impacts. App stores, which are the common online platforms to download an app, provide a star rating system, as well as users’ reviews for patient’s reference. However, the star rating is not helpful with regard to suggesting the actual health benefits to patients. There is an online platform which
recommends ‘trustable’ apps to patients. However, the recommendations are made by patients, their carers, charities and not-for-profit organisations as opposed to being supported by clinical evidence[66]. However, legislators concerned about the legal responsibility associated with telehealth often fail to differentiate between the high and low risk levels of telehealth; potentially adopting an overzealous approach that requires most of the telehealth to be regulated under the ‘medical device’ directive, which slows down telehealth development and suppresses innovations[52].

Figure 6 Illustration of the gap between the requirements of the clinical researchers, technology developer and patients: clinical researchers assessing clinical effectiveness of systems that are out-of-date by the time trials/evaluations are funded and completed; the technology developers seeking maintain patient engagement with frequent ‘updates’ and the patient (and legislators) stuck in the middle with questions about safety.

1.11. Four perspectives and the aim of this PhD

In summary, clinical parties typically focus on the health-related effectiveness and safety of telehealth, rather than seeking patient engagement with the telehealth. In contrast to a focus on safety, the technology parties are well known to have techniques and skills to encourage people’s engagement with their technology, though lack clinical evidence to ensure a patient’s safety. Patients struggle to understand the health impacts of the emerging field of telehealth. The legislative directives[46, 47, 48] potentially slow down telehealth development. Figure 6 (above)
illustrates the gap between the clinical research, healthcare market and the patient’s needs.

To narrow the gap, a new approach is needed for telehealth development. Therefore, in this research, I have combined the MRC complex intervention framework[55] and the Oxford app’s development framework[56], in order to initiate a novel approach to developing an asthma app prototype to support asthma self-management, which I am going to explain next.

Figure 7 Illustration of the inter-related cycles of the framework of the MRC framework and the Oxford app development roadmap

There are similarities and differences between these two frameworks: The MRC framework[55] and the Oxford roadmap[56] are similar in the development and design stages. Firstly, they are looking for evidence, theories to inform the design of the telehealth/app. Secondly, they consider the feasibility of the telehealth/app. Lastly, they evaluate the effectiveness of the telehealth/app. However, their focuses then diverge. The MRC[55] considers the clinical effectiveness of the telehealth (typically with a RCT) whereas the Oxford app development roadmap[56] focuses
on the value of the app and how to attract user engagement. The MRC[55] suggests thinking of the clinical effectiveness of the telehealth at the beginning stage; whereas the roadmap[56] suggests thinking of the business effectiveness of the app at the beginning stage of its life.

Therefore, my approach is to combine these two frameworks to guide the development and design of my intervention. Thus, the intervention is divided into three phases

- phase 1 – identifying evidence base (chapter 3-6)
- phase 2 – modelling key aspects to developing an app prototype and the feasibility study (chapter 7)
- phase 3 – 3 months feasibility study and exploring the legislation issues (chapter 8-10). If funding is available, the findings in this intervention will be used to evaluate and refine the app prototype after this doctoral research.

1.11.1. Use four different perspectives to explore the feasibility

I used four perspectives to explore the feasibility of using an app to support asthma self-management. Table 3 illustrates the questions that I would like to explore from different perspectives. The last column of the table presents the process I used to determine the answers.
Table 3 The four different perspectives to explore the feasibility

<table>
<thead>
<tr>
<th>Phase</th>
<th>Perspectives</th>
<th>Questions</th>
<th>How did I answer the questions in this PhD?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Clinical</td>
<td>What is the current understanding of clinical effectiveness of the mobile technologies to support asthma self-management?</td>
<td>Systematic review (chapter 3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>What are the support features that healthcare professionals and patient would like to see on an app to support asthma self-management?</td>
<td>Three months feasibility study (chapter 8-10)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>What is the role of healthcare professionals when supporting patients with an app?</td>
<td>Three months feasibility study (chapter 8-10)</td>
</tr>
<tr>
<td>1,3</td>
<td>Patient</td>
<td>What are the supporting and application features that patients would like to see and will continue use it on an app?</td>
<td>Online social discussion forum analysis (chapter 4), three months feasibility study (chapter 8-10)</td>
</tr>
<tr>
<td>1,3</td>
<td>Technology/marketing</td>
<td>What are the available features in the current asthma self-management apps in the app stores?</td>
<td>App review (chapter 5)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>What are the technical barriers to use an app to support asthma self-management?</td>
<td>Three months feasibility study (chapter 8-10)</td>
</tr>
<tr>
<td>1,2,3</td>
<td>Legislative</td>
<td>What is the legislative barrier to develop a mobile app to support asthma self-management?</td>
<td>Review our app’s development and the MHRA guidelines on medical device stand-alone software including apps. (chapter 6,7)</td>
</tr>
</tbody>
</table>

1.12. Summary of this chapter

Asthma is one of the most common long term conditions worldwide. It cannot be cured; however, it can be better controlled, thereby hopefully reducing emergency use of healthcare resources, improving asthma outcomes and lowering levels of morbidity because of asthma[24,25,26,27], particularly if patients self-manage their condition. However, the implementation of asthma self-management remains poor in the healthcare services in the UK. Using a mobile app to support asthma self-management has the potential to improve the self-management implementation rates. There is a need to explore an app’s feasibility from the clinical, patients’, technological and legislative perspectives. However, there are gaps between different perspectives. Apart from balancing the requirements from different perspectives, it is also important to develop safe telehealth in a rapid approach. Therefore, a new approach is needed when developing emerging telehealth. Thus, I have combined the existing MRC complex intervention[55] and Oxford app development roadmap[56] to form my study framework. In the next chapter, I will explain the aim and objectives of this research.
Chapter 2  Aim and objectives

2.1  Aim
The aim of this research is to explore the feasibility of using a mobile app to support asthma self-management from clinical, patients’, technological and legislative perspectives.

2.2  Objectives
The objectives of this research are shown as follows

Phase 1: Identifying evidence base
- Clinical perspective: to explore the clinical effectiveness of mobile technologies to support asthma self-management
- Patients’ perspective: to identify mobile technologies features that are important to people using apps and discussed in social discussion forums
- Technological/marketing perspective: to identify features of existing mobile apps which aim to support asthma self-management
- Legislative perspective: to explore the legislative regulation of standalone apps for healthcare purposes

Phase 2: Modelling key aspects to develop an app prototype and the feasibility study
- To develop an app prototype and identify the key questions for the feasibility study

Phase 3: Three month feasibility study
- Patients’ perspectives: To a) compare the attractiveness of the app prototype to patients recruited via their practices or social media, and b) to identify the adoptive and adherent features that influence patients’ engagement with asthma self-management
- Clinical perspective: To identify the supporting features that clinicians want to see on an app to support self-management
- Technological perspective: To explore the practical barriers to use and to pilot an app in clinical practices
- Legislative perspective: To further explore the legislative barriers to develop asthma self-management app to support asthmas self-management
2.3 Objectives and structure of this thesis

2.3.1 Phase 1: Identifying evidence base (Chapter 3 to 6)

Figure 8 Illustration of the process and outcomes in phase 1

In phase 1, I adopted and combined the first stages of the MRC framework[55] and the Oxford app development roadmap[56] in order to identify both evidence and theory to underpin the safety. Also this combination will hopefully facilitate a patient’s acceptability to use an app to support their asthma self-management and to provide information on the potential attractive and adherent features of the app prototype. Attractive features of the app refer to the features that attract user downloads, while the adherent features refer to the features that encourage participants’ use. Figure 8 illustrates the process and outputs in phase 1. I collected evidence from four perspectives: i) clinical: the clinical evidence in the previous randomised controlled trials since the year of 2000, ii) patients: patients’ feedback on app features to support their asthma self-management in the previous 3 years on social discussion forums, iii) technology/ market: the current available features on current asthma self-management apps in the market and iv) legislative: the current situation governing the development of healthcare apps under the medical device directives[46,47,48].
2.3.2 Phase 2: Modelling key aspects to develop an app prototype and the feasibility study (Chapter 7)

In this phase, I used the findings in Phase 1 to modify an existing app platform (in the following contexts, I will call this ‘develop an app prototype’) and to make decisions about the feasibility study (phase 3). To do this, I convened some lay and professional advisory groups and sought advice from our technology partner and university sponsor on legislative matters. The process and outputs of this phase are illustrated in Figure 9. In the chapter, I will provide discussion and justification of the method that I chose; for example: i) How did I choose the features in the app prototype? ii) What were the considerations when I designed the feasibility study? iii) Why did I choose mixed method?
2.3.3 Phase 3: Three month feasibility study (Chapter 8-9)

In phase 3, I conducted a three months feasibility study on the app prototype. Figure 10 gives an overview of the feasibility study. I advertised my app prototype in three different ways: i) GP practice invitation letter to patients with asthma, ii) asthma nurse invitation during asthma review consultation and iii) Asthma UK & Asthma UK for applied research’s (AUKCAR) Facebook and Twitter. I then interviewed patients and healthcare professionals to gain their opinions on, as well as exploring patients’ adoption and usage rates of, the app prototype. I will report the details of the feasibility study (for example, the setting, study design and participant recruitment) in the chapter.

2.3.4 Discussion (Chapter 10), implications (Chapter 11) and conclusion (Chapter 12)

In the discussion section, I will discuss the findings in phase 3 and the interpretation to the published works, limitations and strengths of three months feasibility study. Then I will discuss different implications to different stakeholders and conclude what I have learnt from this PhD work.
Chapter 3 (Phase 1) Clinical perspective: a systematic review of controlled telehealth studies to explore the clinical effectiveness of mobile technologies to support asthma self-management

In this chapter, I will review the clinical impacts from previous telehealth interventions for asthma and identify those features associated with significant positive clinical effects, no significant clinical effects, significant adverse effects and adherence.

Regardless of healthcare services’ or technology developer’s points of view, ‘patient safety’ is the essential requirement for telehealth. Therefore, in keeping with the MRC framework[55] I reviewed the clinical effectiveness of using telehealth to support asthma self-management.

A systematic review, informed by the MRC framework[55], is recommended to identify existing evidence related to the research question. Systematic review methodology provides a standardised framework to identify, evaluate and summarise the available evidence provided by previous clinical research[55,67]. A systematic review helps to explore the clinical effectiveness associated with different features of mobile technologies and provide high quality evidence to underpin the theory in this research. The review protocol was registered with the PROSPERO database (registration number CRD42015016414)[68]; the manuscript was subsequently published in the Journal of the American Medical Informatics Association.
(JAMIA)[69], included in the Appendix 2. In addition to the content being published in the JAMIA, I will provide a more comprehensive explanation on the decisions that I made, together with the results that I found in the following sections.

3.1 Aim of this systematic review

The primary aim for this systematic review was to explore the clinical effectiveness associated with different features of mobile technologies relating to patient self-management. In addition to this primary aim, I was also interested to explore the adoption and adherence to the technologies usage in the past interventions in this systematic review.

3.2 Method

I followed the procedures described in the Cochrane Handbook for Systematic Reviews of Interventions[70] to conduct this systematic review.

3.2.1 Search Strategy

At the beginning, I consulted our systematic review advisor in the university library for help in formulating the search question by the PICOS checklist, picked out major subjects in my question to decide the key words and set criteria for the search to form my search strategy in the following section. I then followed the Cochrane review handbook[70], with reference to the York University Centre for Reviews and Dissemination (CRD) guidelines[67] to outline the protocol[68] according to section 2.2 in the handbook[70]. Table 4 summarises my Population, Intervention, Comparison, Outcome and Setting (PICOS) strategy and the reasons to justify my decisions. I searched nine databases, two trial registries and undertook manual searches of key relevant journals. Search terms were asthma AND technology terms (three categories: smartphone/tablet app; information and communication technology (ICT) services, devices and platforms). The search was limited to randomised controlled trials and quasi-experimental studies with a date limit of 2000 because this was the year of the approval of the global technical specifications for third generation (3G) cellular systems. This approval, under the brand IMT-2000, was granted by the International Telecommunication Union (ITU), so enabling faster ICT application and services, including voice, fax and internet)[71]. The detailed search strategy of the nine databases is provided in Appendix 3.
Table 4 Definition in this systematic review, search strategy and reasons for these choices (reproduced with consent [69])

<table>
<thead>
<tr>
<th>Definition in this systematic review</th>
<th>Inclusion and exclusion criteria, data range and sources of searches</th>
</tr>
</thead>
</table>
| • ICT(s) defined as any information and communication technology(ies) consisted of communication device(s), software(s), app(s) and Web application(s), to allow duplex communication between medical professional(s), patient(s), carer(s) to support asthma self-management.  
• Communication device(s) defined as any communication hardware(s) such as 3G mobile phone, tablet, computer, smart TV, 2G mobile phone and landline telephone to allow duplex communication. | |
| Population                          | Adults and teenagers with asthma. I excluded young children i) because the format of effective self-management in pre-school children is unclear and ii) because the dynamics of ICT use is likely to be different if it is the parent who is taking responsibility. I did not set an absolute age threshold, but included any intervention in which the primary target is the person with asthma (as opposed to a parent); I anticipated this would include teenagers of 12 years and over. Studies of multiple conditions were included if data specifically about people with asthma could be extracted. |
| Intervention                        | Any ICT intervention with any currently available device, such as smart phone, tablet or, smartTV or computer to support self-management of asthma. I did not include interventions where the only ICT component was the use of a telephone as an alternative mode of delivery of a consultation, or to impart information (e.g. with an educational video) unless there was ongoing facilitation of self-management; because I was interested in the ICT to support patient’s asthma self-management only. |
| Comparator                          | Patients who were not provided with, or did not have access to the ICT system to support their asthma self-management; because I was interested in the clinical impacts by using an ICT to support asthma, and compared the difference between telehealth and usual care to support asthma self-management. |
| Outcomes                            | a) Clinical effectiveness (asthma control, acute exacerbations, intermediate outcomes such as self-efficacy  
b) Adoption of ICT was assessed by proportion downloading the apps, or taking up the ICT intervention, ownership of Personalised Asthma Action Plans.  
c) Adherence to ICT intervention was assessed by system usage frequency, withdrawals |
| Settings                            | Any healthcare setting. |
| Study design                        | Studies were included if they were randomised controlled trials (RCT) and quasi experimental studies. |
| Other exclusion criteria            | I excluded papers not published in English; because I did not have resources to translate papers which were not written in English. |
| Date range                          | The date range for all searches commenced in 1st January 2000 to 1st January 2015. Updated search in April 16, because this was the year of the approval of the global technical specifications for third generation (3G) cellular systems under the brand IMT-2000 by the International Telecommunication Union (ITU) which enable faster ICT application and services, including voice, fax and internet |
| Databases                           | MEDLINE; EMBASE; CINAHL; PsychINFO; AMED; BNI, Cochrane library (Database of Abstracts of Reviews of Effects; Cochrane Database of Systematic Reviews, CDSR; Cochrane Central Register of Controlled Trials, CENTRAL), Web of Science Core Collection and ISI Proceedings (SCI-EXPANDE; SSC; A&HCI; CPCI-S; CPCI-SSH; BKCI-S; BKCI-SSH), ScienceDirect |
| Manual searching                    | Journal of Medical Internet Research (2010-2015), Journal of Asthma (2010-2015), Journal of Telemedicine and e-Health (2010-2015); because they were the journals where most of the searched papers were came from. |
| Forward citations                   | A forward citation search was performed on all included papers using ISI Proceedings (Web of Science). The bibliographies of all eligible studies were scrutinised to identify additional possible studies |
| Unpublished and in progress studies | UK Clinical Research Network Study Portfolio (www.clinicaltrials.gov) and the Meta Register of Controlled Trials (www.controlled-trials.com) |
3.2.2 Screening

I screened the first 100 titles and abstracts. These 100 random titles were then checked by my main supervisor (HP) for training and quality control. We reached 100% agreement after discussion. Once I was confident in the criteria used, I screened all the remaining titles and abstracts.

After that, I retrieved and assessed the full text of all potentially eligible studies against the inclusion criteria (see table 1 PICOS description), with a random sample of 20 papers reviewed by a second reviewer (TJ). Disagreements were resolved by discussion and we subsequently achieved 100% agreement.

3.2.3 Data extraction

I extracted data using a piloted data extraction sheet under the headings: a) characteristics of the included studies (study method, demographics of participants, asthma severity, sample size, intervention duration, intervention and control setting); b) features of the ICT; c) clinical outcomes (control and exacerbations); and d) adherence. My main supervisor (HP) undertook duplicate data extraction of key quality and outcome data; disagreements were resolved by discussion.

3.2.4 Risk of bias

I and my main supervisor (HP) assessed and documented the methodological quality of included studies using the methods detailed in section eight of the Cochrane Handbook for Systematic Reviews of Interventions[70], and used Review Manager 5.3 to record and generate the risk of bias graph of the studies. The studies were assessed using the Cochrane Effectiveness and Practice Organisation of Care (EPOC) guidelines[72]. Each parameter of trial quality was graded: A - low risk of bias; B - moderate risk of bias; C - high risk of bias. An overall assessment for each controlled trial using the same three criteria was made. The overarching risk of bias was summarised based on the Cochrane ‘Risk of Bias’ tool[70].

3.2.5 Dealing with potential studies with an abstract only

I contacted the authors where conference abstracts met my inclusion criteria but no publications were available in the database. Missing publications that were not received by the time of my publication submission to JAMIA, were not included.
3.3 Data synthesis and analysis

3.3.1 Meta-analysis

I extracted the outcome measures, setting and duration in a table, and then assessed the heterogeneity of the included studies to judge the appropriateness of performing meta-analysis. I discussed my judgement with a statistician (RP) and my main supervisor (HP). For groups of trials where meta-analysis was judged appropriate, mean difference was estimated using a fixed-effect model via the software R[73], and a pooled estimate with 95% confidence intervals reported. I used a fixed effects method due to the small number of studies and so that the weightings could be more dependent on the within-study variability and study size rather than being influenced by estimates of heterogeneity. If long term and short term measures were presented, the long term measures were taken to determine the treatment effect of the intervention. Measures determining the same outcomes with different scales were not combined by using the standardised means difference (SMD) as the process changed the clinically significant threshold during standardisation. For example, the measures of ACT and ACQ were not combined, whereas different measures determining the same outcome with same scale, such as (ACQ & ACQ-5; AQLQ and mini. AQLQ were further examined the heterogeneity for meta-analysis. These outcome measures are listed in Table 5)

3.3.2 Narrative synthesis

I performed a narrative synthesis of heterogeneous studies because there were diversities in the included interventions in terms of their application features, outcomes measurements; and the number of the included interventions was small. I then plotted the features of each intervention and their association with outcomes, sample size and intervention duration on a bubble plot which enabled identification of a combination of features for effective clinical outcomes and/or adoption and sustainability.

3.3.3 Assessment of clinical importance

With reference to the ATS/ERS Standardizing Endpoints for Clinical Asthma Trials and Clinical Practice[30], I assessed the clinical significance of outcome measures with reference to the suggested minimal important difference; deciding whether
interventions reported ‘positive effects’, ‘no effects’ or ‘adverse effects’. These decisions were reviewed by my supervisors for acceptable quality control.

3.3.4 Data presentation (bubble plot versus harvest plot)

Apart from the meta-analysis and narrative synthesis suggested in the Cochrane guidelines[70] I needed other tools to synthesise the application features, intervention length and sample size which might affect the efficacy of the telehealth. With a view to more clearly illustrating results, I investigated the use of harvest plots, correlation analysis and bubble plots. A harvest plot is a tool to synthesise evidence with their impacts on different factors such as participant’s age, gender and incomes[74]. I decided on a bubble plot because harvest plots cannot report the clinical outcomes with regard to different telehealth features, intervention length and sampling size.

Correlation and meta-analysis were not feasible, as the number of included interventions was too small (n=12), the resolution was not precise enough to allow a meaningful analysis. By contrast, a bubble plot can present the application features, intervention length and sampling size and the clinical effectiveness on a plot to assist descriptive synthesis.

3.3.5 Interpretation

I discussed the results of the data synthesis within the multidisciplinary team which included expertise in e-health, ICT and asthma self-management, and with public patients and public involvement advisors.

3.4 Results

3.4.1 Included studies

I identified 1,919 papers in the search, 14 were finally included[75-88], reporting 12 different studies. I contacted seven authors (Finkelstein[89], Sparrow[90], Cicutto[91], Ahmed[92], Arguel[93], Sciamanna[94], Wiecha[95]) whose abstracts were considered relevant to this systematic review. One author[95] replied with a full text publication, however, his study was excluded due to a lack of any ongoing facilitation of self-management in the intervention; an omission revealed after the
full text was screened. No other replies had been received by the submission date of this review.

Van Gaalen[76] is a long term follow-up of Meer[82] and Cruz-Correia[84] presents the adherence and feasibility data of Araujo[79]. The papers identified, the screening process and the final number of studies included, are detailed in the PRISMS flowchart (Figure 12).

![PRISMS flow diagram](image)

**Figure 12 PRISMS flow diagram**

3.4.2 Characteristics of included studies

The characteristics of the 12 included studies were summarised in table 2, details were reported in Appendix 6 Appendix 4. In summary, the studies[75-88] were conducted from 2005 to 2014, in a range of different countries: two from Netherlands[76, 77] and one each from the Australia[75], Croatia[86], China[78], Denmark[85], Portugal[79], Singapore[81], Taiwan[80], Turkey[88], United Kingdom[87] and the United States[83]. All studies are randomised controlled trials; including a cluster RCT[75] and a crossover RCT[79].
Studies are listed by year of publication in order to reflect the rapidly evolving technological environment. 3G was available in the market in 2001 (technically approved in 2000[1]); the first Apple app and Android app were available in the market from 2008[2] and 2009[3] respectively.


<table>
<thead>
<tr>
<th>Author</th>
<th>Trial</th>
<th>Participant characteristics</th>
<th>Inclusion criteria</th>
<th>Clinical effectiveness outcome</th>
<th>Self-efficacy, Adoption and Adherence outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cingi 2015</td>
<td>Mobile app vs Usual care</td>
<td>Secondary care patients n=168; C: 68</td>
<td>Mild to severe persistent asthma, owned a smartphone at least 6 months prior to enrolment.</td>
<td>*Asthma control: Compared to control group, more patients achieved a well-controlled asthma score (ACT&gt;19) than in the control group [I: 49% vs C: 27%, P&lt;0.05].</td>
<td>Adherence: The app group input 90 (70-154) sets of data. 86% of communications were between 08.00 to 18.00. Attrition was greater in the control group (I: 8 vs C: 39)</td>
</tr>
<tr>
<td>Turkey RCT</td>
<td>FU 3 months</td>
<td>Age I: 32yrs (SD 3.7); C: 34.5yrs (SD 8.2) %Female I: 50%; C: 59%</td>
<td></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td>Foster 2014</td>
<td>Personalised adherence</td>
<td>Primary care patients n=PAD:24; IRF:35; PAD+IRD:41; C:43</td>
<td>Suboptimal asthma control and prescribed twice-daily ICS/LABA for 1 month or more</td>
<td>*Asthma control: No between group differences in ACT (p=0.14) nor between reminder vs non-reminder groups.</td>
<td></td>
</tr>
<tr>
<td>Australia</td>
<td>discussion (PAD) vs SmartTrack reminder (IRF) vs Both IRF+PAD vs Usual care</td>
<td>Age PAD:42.3yrs (SD15.6); IRF:40.0 yrs (SD13.7); PAD+IR:39.7yrs (SD17.7); C:40.0 yrs (SD14.1) %Female PAD:63%; IRF:54%; PAD+IRD:49%; C:78%</td>
<td></td>
<td>*Medication adherence: Adherence declined in all groups over 6 months [PAD: from 62% to 35% vs IRF: from 80% to 60%; IRF+PAD: from 85% to 68%, UC: from 62% to 29%]</td>
<td></td>
</tr>
<tr>
<td>Cluster RCT</td>
<td>FU 6 Months</td>
<td></td>
<td></td>
<td><strong>Exacerbations:</strong> No between group differences in patients with &gt;1 severe exacerbation (P=0.06)</td>
<td></td>
</tr>
<tr>
<td>[Unclear risk of bias]</td>
<td></td>
<td></td>
<td></td>
<td>Quality of life: No between group differences in mini AQLQ (P=0.26)</td>
<td></td>
</tr>
</tbody>
</table>

**Table 5 Clinical outcomes of the included interventions** (reproduced with consent[69])
<table>
<thead>
<tr>
<th>Author [BIAS]</th>
<th>Trial</th>
<th>Participant characteristics</th>
<th>Inclusion criteria</th>
<th>Clinical effectiveness outcome</th>
<th>Self-efficacy, Adoption and Adherence outcome</th>
</tr>
</thead>
</table>
| Van Gaalen 2013 Netherlands RCT [LOW risk of bias] | Web-monitoring + education vs Usual care 30month FU of Meer trial | Primary and secondary care patients. n= I:47; C:60 Age. I:36yrs (SD8.7); C:37yrs (SD8.0) %Female I:74%; C:68% | Patients from Meer agreeing to 30month FU | Asthma control: Significant but attenuated between group improvement in ACQ score at 30 month [adj mean df - 0.33 (-0.61 to -0.05)]
*Quality of life: Significant but attenuated between group improvement in AQLQ score at 30 month [adj mean diff 0.29 (0.01 to 0.57)] | N/A |
| Meer 2009 Netherlands RCT [LOW risk of bias] | Web-monitoring + education vs Usual care 12 months RCT | Primary and secondary care patients n= I:101; C:99 Age I:36yrs (range 19-50); C:37yrs (range 18-50)] %Female I:68%; C:71% | Physician-diagnosed asthma on ICS for ≥3 months, access to Internet, Dutch speaking. | Asthma control: Compared to controls, web group had improved ACQ at 12th month [I:-0.54 (-0.65 to -0.42) vs C: -0.06 (-0.18 to 0.05)]
*Quality of life: Compared to controls, web group had improved AQLQ at the 12 month [I: 0.56 (0.43 to 0.68) vs C: 0.18 (0.05 to 0.31)]
Medication adherence: No between-group difference in self-reported medication adherence. | Adherence: An average of 34.8 website log files received from each patient in the web group at the 12 months. No reports on data in the control group |
| Araújo 2012 Portugal Crossover RCT [UNCLEAR risk of bias] | Paper-Web vs Web-Paper FU 48 weeks | Secondary care patients n= I:12; C:9 Age I:26yrs (SD 6.2); C:32yrs (SD12.2) %Female= I:67%; C:78% | Moderate/severe asthma for ≥6 months using ICS/LABA in a single inhaler and a FEV1 >50% predicted | *Asthma control: no between group difference in ACQ-5 [mean diff -0.2 (-0.63 to 0.27), P=0.42]
Quality of life: no between group difference in mini-AQLQ [mean diff -0.1 (-0.33 to 0.49) P=0.68] | N/A |
<table>
<thead>
<tr>
<th>Author/Date</th>
<th>Trial</th>
<th>Characteristics</th>
<th>Inclusion Criteria</th>
<th>Clinical Effectiveness Outcome</th>
<th>Self-efficacy, Adoption and Adherence Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cruz-Correia 2007 Portugal Crossover RCT [UNCLEAR risk of bias]</td>
<td>Same intervention as Araújo</td>
<td>Refer to Araújo</td>
<td>Refer to Araújo</td>
<td>This publication showed the patient's opinions and adherence to monitoring tool only. Clinical effectiveness reported in Araújo.</td>
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</tr>
<tr>
<td>Lv 2012 China, Guangzhou RCT [UNCLEAR risk of bias]</td>
<td>SMS messages vs Verbal education vs Usual care FU 12 weeks</td>
<td>Secondary care patients n= SMS:30; Verbal:14; C:27 Age: SMS:36yrs (SD11); Verbal: 41 yrs (SD 12 ); C:37yrs (SD 12) %Female SMS:33.3%; Verbal:50.0%; C:48.1%</td>
<td>Asthma for ≥3 months (positive bronchodilator reversibility or bronchodilator provocation test)</td>
<td>Quality of life: compare to the traditional [16.52 (SD 21.10)] and control group [4.21(SD 30.98)], SMS group had the highest mean change in AQLQ(S) [31.40 (SD30.42)] p = 0.008</td>
<td>Adherence: Paper diary completion was better than the web-records, [I: 48% vs C: 95%, P&lt;0.001], but use of electronic PEF meter was similar in both groups [I: 50% vs C:50%]. 63% of patients were ‘very interested’ in continuing to use the app</td>
</tr>
<tr>
<td>Rikkers-Mutsaerts 2012 Netherlands RCT [HIGH risk of bias in general]</td>
<td>Web-based self-management vs Usual care FU 12 months</td>
<td>Primary and secondary asthma, ICS in the previous year, access to Internet, and Dutch speaking</td>
<td>Mild-severe persistent asthma</td>
<td>Asthma control: No between group difference in change in ACQ at 12 month [-0.05(-0.35-0.25)]</td>
<td>Quality of life: No between group difference in change in PAQLQ at 12m [-0.05(-0.50 to 0.41)]</td>
</tr>
</tbody>
</table>

* Perceived control of asthma: there was a significant different in the PACQ-6 score between SMS group and the control group [P=0.018]

Adherence: An average of 19.9 website log files received from each patient in the web group at 12month. No information on data recording in the control group. Attrition was greater in the web group (I:11/46 vs C:4/44).
<table>
<thead>
<tr>
<th>Author [BIAS]</th>
<th>Trial</th>
<th>Participant characteristics</th>
<th>Inclusion criteria</th>
<th>Clinical effectiveness outcome</th>
<th>Self-efficacy, Adoption and Adherence outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ryan 2012 UK RCT [LOW risk of bias]</td>
<td>Mobile self-management app VS Usual care FU 6 months</td>
<td>Primary care patients. n=I:145; C:143 Age:46.6yrs (SD18); C:51.1yrs (SD 17.7) %Female. I:66%;C:59%</td>
<td>Poorly controlled asthma , had, or were willing to borrow, a compatible mobile phone handset</td>
<td>*Asthma control: no between group difference in change in ACQ [mean diff 0.02(-0.23 to 0.19)]</td>
<td>*Self-efficacy: no between group difference in change in KASE-AQ self-efficacy mean diff 2.0(-0.3 to 4.2); attitude mean diff -0.2(-1.6 to 1.6)]</td>
</tr>
<tr>
<td>Liu 2011 Taiwan RCT [UNCLEAR risk of bias]</td>
<td>Mobile app VS Usual care FU 6 months</td>
<td>Secondary care patient n=I:43; C:46 Age I: 50.4yrs (SD1.9); C: 54.0yrs (SD2.4) %Female. I:48.8%; C:52.2%</td>
<td>Moderate to severe persistent asthma</td>
<td>Asthma control: compared to the control group. mean FEV_{1} increased at 6 months I: 65.2L/min (SEM 3.2%) vs C: 56.5 (SEM 2.8) P&lt;0.05</td>
<td>Adherence: % participants recording data decreased over time in both groups, I: 71.7% vs C: 76.7% at 6 months. Of the 11 patients who withdrew 4 couldn’t use the app and 2 had problems with the app</td>
</tr>
<tr>
<td>Author [BIAS]</td>
<td>Trial</td>
<td>Participant characteristics</td>
<td>Inclusion criteria</td>
<td>Clinical effectiveness outcome</td>
<td>Self-efficacy, Adoption and Adherence outcome</td>
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<td>Prabhakaran 2010 RCT Singapore [HIGH risk of bias]</td>
<td>SMS symptom monitoring vs Usual care FU 3 months</td>
<td>Secondary care patients n=1:60; C:60; Age 1:37yrs (SD12); C:40yrs (SD13) %Female 1:65%; C:53%</td>
<td>Previous hospital admission, owned a mobile phone, knew how to use SMS and understood English.</td>
<td><em>Asthma control: no between group difference in proportion with ACT≥20 at 3 months 1:36% vs C:28%, P=0.113</em></td>
<td>Adherence: of the 2 patients who withdrew, 1 was dissatisfied with the SMS services</td>
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<tr>
<td>Jacobson 2009 US RCT [UNCLEAR risk of bias]</td>
<td>Electronic asthma monitoring system (AMS) vs Usual care FU 6 months</td>
<td>Primary care patients n=1:29; C:30; Age 1: 6-15 yrs; C:8-15yrs %Female 1:51.7%; C:50.0%</td>
<td>Moderate/severe asthma, ≥ 2 ED visits or 1 hospitalization</td>
<td><em>Exacerbation: No between group difference in the percentage of patients with visited to the emergency department [P=0.8] and hospitalisation [P=0.6].</em></td>
<td>Adherence: Compare to control group, data were received on more days in the AMS group [1:211days vs C:136.6days]</td>
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<tr>
<td>Rasmussen 2005 Denmark RCT [UNCLEAR risk of bias]</td>
<td>Web management tool (Web) vs Specialist care (S) vs Usual care (GP) FU 6 months</td>
<td>Community based patients n=1:29; S:88;GP:80; Age Web:28yrs (18-44); S:30yrs (19-45); GP:30yrs (20-45) %Female Web:68%; S:66%; GP:73%</td>
<td>Asthma diagnosed and living in the catchment area of University Hospital of Copenhagen</td>
<td>Asthma control: OR of improved symptoms: [Web vs S 2.64(1.43-4.88); Web vs GP 3.26(1.71-6.19), S vs GP 1.23(0.66-2.30)] Quality of life: OR of improved AQLQ: [Web vs S 2.21 (1.09-4.47), Web vs GP 2.10 (102-3.41), S vs GP 0.95 (0.43-2.07)]</td>
<td>Adoption: Web group showed a largest improvement in use of action plan (Web=from 2% to 88%; S= from 3% to 55%; GP: from 0% to 6%) compared to the specialist and GP groups</td>
</tr>
<tr>
<td>Author</td>
<td>Trial</td>
<td>Participant characteristics</td>
<td>Inclusion criteria</td>
<td>Clinical effectiveness outcome</td>
<td>Self-efficacy, Adoption and Adherence outcome</td>
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<tr>
<td>Ostojic 2005 Croatia RCT</td>
<td>SMS transmission of monitoring data vs Usual care FU 6 months</td>
<td>Secondary care patients n=1:8; C:8 Age 1:24.8yrs (SD 6.3); C:24.5yrs (SD7.1) %Female 1:37%; C:50%</td>
<td>Persistent asthma for at least 6 months and were being treated with ICS and LABA, experienced in SMS</td>
<td>Asthma control: Compared to control group, SMS group had lower control cough symptom score: 1:1.42 (SD 0.28) vs C: 1.85 (SD 0.43), (P&lt;.05), and night symptom score 1:0.85 (SD 0.32) vs C: 1.22 (SD 0.23) (P&lt;0.05) Exacerbation: No between group difference in number of office visits [1:21 vs C:15] or hospital admissions [1: 2 vs C:7]</td>
<td>Adherence: 1769 sets of data were received by SMS. No reports on the recording of data in the control group</td>
</tr>
</tbody>
</table>

3.4.3 Risk of bias

The risk of bias across interventions is summarised in Figure 13, details are reported in the appendix 4. In summary, there were important issues in the risk of bias assessment, as set out below.

- In studies of telehealth, blinding of participants is generally impossible but some trials ensured that researchers were blind or used a self-reported method to collect data so to reduce the researchers’ influences to patients’ inputs. These outcome measurements were unlikely to be influenced by lack of blinding and so those studies were judged as having a ‘low risk of bias’. One study team (Prabhakaran[81]), collected outcome data using the asthma nurse who could identify patients in the intervention, a procedure which was likely to introduce bias.

- One study (Rikkers-Mutsaerts[77]) gave cause for concern because of an attrition rate of 11/46. Also there was a difference between the baseline characteristics of the control and intervention groups.

- Lv[78] and Liu[80] did not clearly indicate their strategies to minimise the potential bias regarding the issues of selection, detection, attrition and reporting.
<table>
<thead>
<tr>
<th>Study</th>
<th>Random sequence generation (selection bias)</th>
<th>Allocation concealment (selection bias)</th>
<th>Blinding of participants and personnel (performance bias)</th>
<th>Blinding of outcome assessment (detection bias)</th>
<th>Incomplete outcome data (attrition bias)</th>
<th>Selective reporting (reporting bias)</th>
<th>Other bias</th>
</tr>
</thead>
</table>

Figure 13 Risk of bias across intervention (reproduced with consent[69])
3.4.4 Participants

The numbers of participants for each intervention ranged from a minimum of 16 to a maximum of 300. The research populations were recruited from primary and/or secondary care, with mild/moderate, severe persistent or poorly controlled asthmatic conditions. Others participants were patients who had been admitted to hospital. Most studies included a mixture of teenagers and adults; though one intervention[83] also included children from 8 years old. Six interventions[76, 77, 81, 86, 87, 88] additionally required patients to have access to the internet or own a mobile phone with mobile network capability and/or know how to use the short messaging service (SMS).

3.4.5 Interventions

Of the twelve ICT interventions, three were mobile phone apps[80, 87, 88], four web applications[76, 77, 79, 85] one of which used peak flow monitoring; three SMS[78, 81, 86], one electronic inhaler reminder system connected with web application[75], and one used a customised asthma monitoring system with 4-key keypad for data entry, and data transmitted by telephone line[83].

3.4.6 Comparisons

In most studies, the comparator was patients without access to any ICT systems supporting their asthma self-management; however, one study had two comparator groups (usual care and verbal self-management advice)[85], and one other had two components (reminders and professional consultation skills training) compared or combined in four groups[75].
3.4.7 Clinical outcomes

Three clinical outcomes were summarised in Figure 15, Figure 16 and Figure 17, with further details in Appendix 4. The common clinical outcomes were: a) asthma control, b) quality of life and c) exacerbation.

Meta-analysis for asthma control

![Figure 14 Forest plot for the meta-analysis of the asthma control and the asthma control outcome of the long term follow up study of Meer (reproduced with consent[69])](image)

Four publications[76, 77, 82, 83] reported asthma control using the Asthma Control Questionnaire (ACQ), three of which are included in the meta-analysis. One study, (Araujo)[79], was excluded because it used a shorter version of the ACQ (ACQ-5), which meant that it was not appropriate to combine this study with the other RCTs which used the full version of the ACQ. There was a statistically significantly improved asthma control in the intervention group (mean difference -0.25 (95%CI -0.37 to -0.12)), but the confidence interval did not include the minimum clinically important difference of 0.5[96](see the Forest plot: Figure 14). In addition, Van Gaalen[76], in the follow-up study of Meer[82], reported ACQ. The between-group difference was maintained, albeit attenuated (-0.33 CI -0.61 to 0.05) for the 107 patients (60.8% of the participants in the original trial) who contributed data at 30 months[76].
Publication bias

A funnel plot was not used to detect the publication bias because Cochrane[70] (chapter 10.43.1) suggests at least ten studies are needed in the meta-analysis; I had just three studies in the meta-analysis.

Narrative synthesis: asthma control

In six of eleven studies[76, 78, 80, 85, 86] researchers reported improved asthma control over timescales of 3 to 30 months in the intervention groups. The interventions consisted of two mobile apps, two web applications and two SMS services. A common feature was an electronic diary which could be shared with healthcare professionals for regular review. Of the six interventions, one[86] was at low risk of bias while five interventions[76, 78, 80, 85] showed ‘unclear’ risk of bias.

Quality of life

Although eight studies[75-80, 85, 87] reported asthma-related quality of life, heterogeneity of study design and the outcome measures used precluded meaningful meta-analysis. Four interventions[76, 78, 80, 85] (4, 50%) found that quality of life improved over 6 to 30 months. The interventions were web applications with common features, such as: a) an electronic diary, b) an action plan, and c) regular supportive reviews by healthcare professionals. Of the four effective interventions, one study was at ‘low risk of bias’[76] while three were at ‘unclear’ risk of bias[78, 80, 85].

Exacerbations

Five interventions[75, 81, 83, 86, 87] reported six outcomes relevant to exacerbations: i) hospital admissions, ii) emergency department attendance, iii) unscheduled visit to practices, iv) steroid courses, v) numbers of patients with one or more severe exacerbations, and vi) healthcare professionals’ visits triggered by an exacerbation alert generated by the ICT system. The interventions were: a) a mobile app, b) a smart inhaler, c) a handheld asthma monitoring device and d) SMS services. None of the interventions were associated with a significant reduction in exacerbation-related outcomes. Three of the studies[83, 86, 87] presented data on
proportions of patients with a hospital admission over a period of between 3 to 6 months, but the rates were very close to zero (0.02%, 0.17% and 0.25%) so that meta-analysis was unhelpful. Of five interventions, three studies were at ‘unclear’ risk of bias[75, 83, 86], one was at ‘low’ risk of bias[87] and one was at ‘high’ risk of bias[81].

3.4.8 Application features in the included interventions

Characteristics of the application features

There were eleven application features in the twelve interventions, details of which are summarised in Table 6. These features were categorised into nine themes with reference to the PRISMS self-management support components[34]; a) information about condition and/or its management, b) monitoring of condition with feedback, c) provision of action plan, d) practical supports for medication adherence, e) training/rehearsal to communicate with healthcare professionals, f) regular consultation, g) provisions of equipment, h) training for practical self-management activities. One was a support for healthcare professional which is not included in the PRISMS taxonomy: i) decision support for the healthcare professional. Eleven of the 12 interventions included more than one feature, as follows:

- Six interventions included five or more features
- Eight included an asthma diary, nine included an action plan, and eleven professional support
- Only one intervention[85] contained a decision support system for the healthcare professional.
### Table 6: Application features of the included interventions (reproduced with consent[69])

<table>
<thead>
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</thead>
<tbody>
<tr>
<td>A. Information about condition and/or its management [3, 25%]</td>
<td>A1. Provides links of online learning resources (e.g. asthma information, news, FAQ) with face to face education by specialized nurse</td>
<td>✓</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>✓</td>
<td>x</td>
<td>x</td>
<td>x</td>
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<tr>
<td>B. Monitoring of condition with feedback [8,67%]</td>
<td>B1. Provides electronic diary to log symptoms, PEF or FEV1, ACQ for decision making during intervention</td>
<td>✓</td>
<td>x</td>
<td>✓</td>
<td>x</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>x</td>
<td>x</td>
<td>x</td>
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<td>x</td>
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<td></td>
<td>Health status (7-point scale) with emoticon</td>
<td>x</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td></td>
<td>FEV1 and ACQ</td>
<td>x</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td></td>
<td>symptom, PEF, FEV1</td>
<td>x</td>
<td>✓</td>
<td>✓</td>
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<td>FEV1 and ACQ</td>
<td>x</td>
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<td>C. Provision of action plan [9.75%]</td>
<td>C1. Provides advice (treatment adjustment advise)</td>
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<td>C2. Identify exacerbation/urgent messages</td>
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<tr>
<td></td>
<td>Patient self-report to physician, triggered an voice notification in physician’s app</td>
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<td>System suggested patient to contact physician, patient chose to contact physician</td>
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<td>System detected asthma not under controlled, auto alert generated to physician</td>
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<td>System detected asthma not under controlled, auto alert generated to physician</td>
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<tr>
<td>D. Practical supports for medication adherence [2, 17%]</td>
<td>D1. Log daily prescribed medication</td>
<td>✓</td>
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<td>D2. Reminder for medication</td>
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<tr>
<td>E. Training/rehearsal to communicate with healthcare professionals [11, 92%]</td>
<td>E1. Shares electronic diary/report to professional for review via shared database</td>
<td>✓</td>
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<tr>
<td>F. Regular consultation [4, 33%]</td>
<td>F1. Regular consultation by professional</td>
<td>✓</td>
<td>✓</td>
<td>✗</td>
<td>✗</td>
<td>✓</td>
<td>✓</td>
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<td>✗</td>
<td>✗</td>
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<tr>
<td>G. Provision of equipment [1, 8%]</td>
<td>G1. Providing smart inhaler or handheld device</td>
<td>✗</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✗</td>
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<td>✓</td>
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<td>H. Training for practical self-management activities [2, 17%]</td>
<td>H1. Pop up questions and feedbacks</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
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<tr>
<td>I. Decision Supports for physician [1, 8%]</td>
<td>I1. DSS for the physician</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
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</table>
3.4.9 Application features associated with the health-related outcomes of the included intervention

To synthesise the impact of the application features on the health-related outcomes while also considering the sample size and duration of each study, I prepared bubble plots (see Figure 15 to Figure 17 below). The effect on asthma control and quality-of-life was inconsistent, though there were no examples of harm. There was no significant clinical impact, either positive or adverse, on exacerbations[75, 81, 83, 86, 87]. Most of the interventions included multiple features involving self-monitoring and action plans, but outcomes were variable. One study that focused on medication adherence via reminders and treatment logs, improved adherence but did not influence any of the clinical outcomes[75]. One study which incorporated feedback and decision support for physicians[85] improved asthma control and quality-of-life.

Figure 15 Clinical outcome: asthma control (reproduced with consent[69])
Figure 16 Clinical outcome: quality of life (reproduced with consent[69])

Figure 17 Clinical outcome: exacerbation
3.4.10 Adoption and adherence to usage

Action plan ownership

Within the twelve studies, only one study[85] reported action plan ownership in the three study groups. A significant increase in the use of an action plan from baseline to end of study was reported in both intervention groups (web-based monitoring: from 2% to 88%; web-based specialist support from 3% to 55%) compared to a smaller increase in the usual care group (from 0% to 6%).

Self-efficacy

Only one study reported on the variable of self-efficacy[87]. The intervention was a mobile app which provided patients with an asthma diary, action plan and structured support from the healthcare professionals for six months. No significant difference was reported in self-efficacy between the intervention and control groups, which had similar professional support (KASE-AQ, self-efficacy score: mean difference 2.0 (95%CI -0.3 to 4.2).

3.4.11 Adoption and adherence to the intervention

There were no interventions that explicitly reported adoption of the ICT system. It is impossible to gauge adoption directly in a trial because, by definition, everyone in the intervention group receives the ICT system. However, usage data may give an indication of the general level of interest in the ICT system; equally, adherence to the ICT system may be inferred by looking at differential attrition rates in the intervention/control groups and reasons for withdrawal. Eight studies reported the data transmitted during the studies and/ or reasons of the attrition, because of problems with the ICT system(s). Details are summarised in Table 7.
<table>
<thead>
<tr>
<th>Author</th>
<th>Adoption and Adherence outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cingi 2015</td>
<td><strong>Adherence</strong>: The app group inputted 90 (70-154) sets of data. 86% of communications were between 08.00 to 18.00. Attrition was greater in the control group (I: 8 vs C:39)</td>
</tr>
<tr>
<td>Foster 2014</td>
<td>N/A</td>
</tr>
<tr>
<td>Van Gaalen 2013</td>
<td>N/A</td>
</tr>
<tr>
<td>Meer 2009</td>
<td><strong>Adherence</strong>: An average of 34.8 website log files received from each patient in the web group at the 12 months. No reports on data in the control group</td>
</tr>
<tr>
<td>Araújo 2012</td>
<td>N/A</td>
</tr>
<tr>
<td>Cruz-Correia 2007</td>
<td><strong>Adherence</strong>: Paper diary completion was better than the web-records, [I: 48% vs C: 95%, P&lt;0.001], but use of electronic PEF meter was similar in both groups [I: 50% vs C:50%]. 63% of patients were ‘very interested’ in continuing to use the app</td>
</tr>
<tr>
<td>Lv 2012</td>
<td>N/A</td>
</tr>
<tr>
<td>Rikkers-Mutsaerts</td>
<td><strong>Adherence</strong>: An average of 19.9 website log files received from each patient in the web group at 12 month. No information on data recording in the control group. Attrition was greater in the web group (I:11/46 vs C:4/44).</td>
</tr>
<tr>
<td>Ryan 2012</td>
<td>N/A</td>
</tr>
<tr>
<td>Liu 2011</td>
<td><strong>Adherence</strong>: % participants recording data decreased over time in both groups, [I: 71.7% vs C: 76.7% at 6 months. Of the 11 patients who withdrew 4 couldn’t use the app and 2 had problems with the app</td>
</tr>
<tr>
<td>Prabhakaran 2010</td>
<td><strong>Adherence</strong>: of the 2 patients who withdrew, 1 was dissatisfied with the SMS services</td>
</tr>
<tr>
<td>Jacobson 2009</td>
<td><strong>Adherence</strong>: Compare to control group, data were received on more days in the AMS group [I:211days vs C:136.6days]</td>
</tr>
<tr>
<td>Rasmussen 2005</td>
<td><strong>Adoption</strong>: Web group showed a largest improvement in use of action plan (Web: from 2% to 88%; S: from 3% to 55%; GP: from 0% to 6%) compared to the specialist and GP groups</td>
</tr>
<tr>
<td>Ostojic 2005</td>
<td><strong>Adherence</strong>: 1769 sets of data were received by SMS. No reports on the recording of data in the control group</td>
</tr>
</tbody>
</table>
Of the eight interventions, only two (Aroujo[79], and Jacobson[83]) reported the data transmitted in the control and intervention groups. Araujo[79] reported there was no significant difference between adherence to electronic peak flow monitoring when comparing participants using the web application group and paper-based monitoring. At the end of the trial, 12 of the 18 participants in the cross-over trial were ‘very interested’ in continuing to monitor their asthma using the web application. Another study, Jacobson[83], reported 2.8 times more data received from the intervention group than the paper-based group. Araujo[79] employed a web application while Jacobson[83] used a customised embedded system. They both had the application features of an action plan and facilitated support from healthcare professionals.

Three interventions explicitly reported the number of patients who, for whatever reasons, were lost to follow up or who withdrew because of the problems with the ICT systems. The three studies were: i) Ryan[87] (n=5, ‘telemonitoring problem’), ii) Liu[80] (n=4 ‘couldn’t use the app’; n=2 had a ‘problem with the app’) and iii) Prabhakaren[81] (n=1, ‘dissatisfied with the service’). Ryan[87] and Liu[80] were investigating mobile app interventions while Prabhakaren[81] used a SMS application. They all had the application features of asthma diary, action plan and with the support from healthcare professionals.

3.5 Discussion

3.5.1 Summary of findings

My meta-analysis of three trials showed a positive effect on asthma control, and a 30 month follow-up study showed that this effect was sustained, albeit attenuated. Within the twelve studies[75-88], I identified eleven common features grouped into nine themes. Most of the interventions included multiple features of self-monitoring and action plans. The effect of the features on the main health-related outcomes of asthma control, quality of life, and exacerbations, as well as with medication adherence, all varied; although importantly there were no examples of harm. There was no significant positive or adverse clinical impact on exacerbations[75, 81, 83, 86, 87]. The impact of the different features on adoption and adherence to the system was not possible to gauge directly, but
the reasons given to explain attrition rates highlighted the importance of reliable, user-friendly systems.

3.5.2 Strengths and limitations

This systematic review provides evidence explicitly related to the ICT features included in interventions reported since 2000; and specifically the interventions’ association with asthma health-related outcomes. I performed an updated search in early April 2016. Nevertheless, in the fast moving field of ICT, this more recent search may still have missed some contemporary features. None of the included interventions reported adverse health outcomes, which could possibly be an indication of publication bias.

There are some methodological limitations. First, due to resource and time constraints, a single review was performed at the initial screening stage of this study; however, I implemented robust training, and quality control processes during the review, in order to minimise potential inaccuracies. Second, I did not translate papers that were not written in English; only one study in this category (Kokubu, 2000 in Japanese)[97] was identified. Third, the included trials focused primarily on health outcomes and the interventions included multiple features; therefore, they could not provide evidence on the individual application’s features. It is possible my grouping of the features may be useful for further research. Fourth, there was a lack of descriptions of technical features in most of the included interventions; an omission which means I may not have interpreted the intervention accurately. Last, there were no interventions which showed significant adverse health impacts on patients; an interesting result that might be due to publication bias, where adverse outcomes were not published.

3.5.3 Interpretation in relation to published literature

My findings were in line with other reviews[98, 99, 100, 101], which showed that the impact of ICT interventions designed to support asthma self-management had an inconsistent impact on the recipients’ asthma control and quality of life. The core elements of effective self-management, as recommended by the BTS/SIGN British asthma guideline[24], are education, an action plan, and regular professional reviews. Two[76, 88] of the three interventions[76, 78, 88] incorporating these elements showed
an improvement of asthma control. A review[54] suggested that providing instruction focusing on better healthcare management and sharing data with a designated professional were the most valuable features of healthcare apps for users. Interventions with these features (see the bubble plot; Figures 4 and 5) found that impact on asthma control and quality of life varied, and there was no significant impact on exacerbations.

The inconsistent clinical outcome from the 11 studies, despite incorporating similar features, highlights the importance of context in determining whether an intervention is effective. This resonates with the findings of a systematic review of studies implementing supported asthma self-management, which concluded that a whole systems approach which explicitly addressed patient, professional and organisational related factors, showed the most consistent improvement in clinical outcomes[102]. Of the 12 studies in this current review, the 11 studies with application features focused solely on patients, showed inconsistent impacts on clinical outcomes; the one study with features targeted at both patients and healthcare professionals improved both asthma control and quality-of-life.

There are 14 self-management support components summarised in the PRISMS taxonomy[34]. The included studies involved application features in nine PRISMS components[34]. They were a) information about condition and/or its management, b) monitoring of condition with feedback, c) provision of action plan, d) practical supports for medication adherence, e) training/rehearsal to communicate with healthcare professionals, f) regular consultation and g) provision of equipment and h) training for practical self-management activities, i) decision support for the healthcare professional. A recent review of the systematic reviews of telehealth on asthma[100], suggested a similar result, the summarised interventions involved features to support information about condition and/or its management, monitor of condition with feedback as well as to support clinic review.
3.6 Implications for future work

My findings suggest that mobile apps yield inconsistent clinical benefits, although I did not discover any significant adverse health impacts on patients. This review also suggests that apps have the potential to be effective in supporting asthma patients’ self-management and are therefore an option that may be preferred by some people and their clinicians. However, these studies of multifaceted interventions did not provide clear evidence identifying which of the range of ICT features were essential for effectiveness. Furthermore, the lack of technical specifications of the ICT systems evaluated in the clinically-focused publications involving health outcomes, did not provide any understanding of the design factors of the ICT system. As a result it was not possible to know what variables may have affected how the systems operated, or how they were used by patients and professionals. Finally, no matter how well designed the ICT was, it was not effective if patients did not adopt it and then continue to use it. The challenge for me now is to explore the dynamic needs and preferences of people with asthma and to evaluate the features associated with improved adoption of, and adherence to, mobile apps.

Conclusion from the systematic review

Further developments in this field require robust studies not only establishing the long term effectiveness of mobile apps designed to support asthma patients but also evaluating specific features associated with improved adoption and adherence by patients to the mobile app. In the context of this research, further analyses are needed to identify features patients would like to see in an asthma app to support their self-management.
Chapter 4 (Phase 1) Patients’ perspectives: to identify mobile technologies features that are important to people using apps and discussed in social discussion forums

In this chapter, I explore how patients ‘feel’ about using an app to support asthma self-management and what features that they would like to see in such an app (Appendix 5, the paper was accepted for presentation by the BCS conference and the publication is in press.)

4.1 Rationale for this study

As mentioned in the introduction (section 1.8.2), technologies change rapidly. Therefore, the findings from previous studies may not be applicable to all contemporary technologies; only a few were generalisable. Mendiola[54] was one of those, in which the researcher conducted a content analysis to identify the features that patients’ valued in healthcare apps. Huckvale[44] conducted a systematic assessment to summarise the evaluation of asthma apps. Whilst the findings provided generic suggestions, they were not sufficiently helpful to suggest what support patients would like to see in an asthma management app. Therefore, I decided to conduct a social forum analysis to explore this
issue. From the analysis, I aimed to gain preliminary information about patients’ thoughts on using an app, or other technologies, to look after their asthma; in particular, which supporting features they liked and which they disliked. The findings were then to be used to shape the app prototype and inform the feasibility study design in the next phase of the work. As a result, these reviews had to provide a wide spectrum of patients’ preferences in a short time. A quick data mining and analysis approach to this challenge was needed.

There were different methods of obtaining such information that I considered before I chose a social forum analysis format. These method options were: a) online questionnaires, b) interviewing patients, c) reviewing an online social discussion forum and d) reviewing asthma apps’ features associated with their download rate on app stores.

- **Online questionnaire option:** it is one of the commonest methodologies to collect feedback from users. However, it required time to design the questions and set up the questionnaire system; also promotion was needed. In addition, the number of replies in relation to baseline would be unknown and may not be representative.

- **Interviewing patients:** it is a direct way to hear patients’ opinions, allowing in-depth exploration of opinions which I intended to use in phase 3. However, in this phase, the time required to clear ethics and to complete the recruitment of participants would have created unacceptable delays to the following phases of the project.

- **Online social discussion forum analysis:** it would allow me to extract patients’ feedback on real time platforms, meaning that their feedback was up-to-date with, and therefore informed by, recent technology. Furthermore, time would be saved on recruiting and setting up questions to patients. However, I recognised that the findings may not be generalisable to patients who, for whatever reasons, did not use social media.

In the end, I decided to conduct the online social discussion forum analysis after consultations with my supervisors, as well as with a colleague with user-usability
expertise in the University’s Informatics School (MW). My decision aimed to capture patients’ opinions on emerging technologies in the rapid life cycle of technology, based on the time resources that were available for this project, as well as the information that I needed. Details of the strengths and limitations of this analysis will be discussed in section 4.7.2. In the following sections, I will discuss the details of this analysis.

### 4.2 Aim of the online social discussion forum review

My primary interest was i) to identify any telehealth issues that were discussed by people with asthma and ii) in telehealth, to discover what supporting features patients valued and therefore wanted to see in ‘their’ app.

### 4.3 Method

I have written a manuscript which was peer reviewed and accepted by the British Computer Society conference (in press). In addition to the content of the submitted manuscript, I will provide a more comprehensive explanation on the decisions that I made and the results that I found in the following sections.

#### 4.3.1 Social discussion forum search

Social discussion forums are online websites where people can discuss any issues in the form of posted messages. I aimed to include forums which people were able to find easily on-line and on which they could post their thoughts about their asthma. Therefore, informed by the Google search guide I performed searches on 17th November, 2015 using a combination of the key terms of ‘asthma’ and ‘forum’. The first 20 results were reviewed from each search and the name and link of the forums were extracted and then formatted into a table. Other forums recommended by colleagues from the Asthma UK Centre for Applied Research were also included. An updated search was performed on 8th January, 2017, applying the same criteria.

#### 4.3.2 Thread search and selection

I performed local searches within each of the included forums. If a local search facility was not provided in the site, the Google search engine was used to perform the local forum search by using the universal syntax (site:[url] [search term]) recommended by
the Google search guide[103]. ‘Asthma’ AND (‘app’ AND/OR ‘gadget’ AND/OR ‘smartphone’) were used as the key search terms for the threads. The search was restricted to English language sites. Searched threads were assessed by the inclusion and exclusion criteria set out in Table 8.

Table 8 Search strategy

<table>
<thead>
<tr>
<th>Inclusion criteria</th>
<th>Smartphone or tablet app* features to support asthma self-management. Thread (a query or comment) that mentioned any features a) to support asthma self-management or b) made by someone with asthma.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Key:*app - we included standalone app, web-based app and app connected with smart devices such as smart inhaler, smart peak flow meter, indoor air monitor and pedometer</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Exclusion criteria</th>
<th>First filter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unrelated discussion which did not mention features of asthma apps and/or asthma</td>
</tr>
<tr>
<td></td>
<td>No replies to the thread as simplex communication increase the uncertainty of understanding the writer’s feelings on the features</td>
</tr>
<tr>
<td></td>
<td>The application features were for children only</td>
</tr>
<tr>
<td></td>
<td>New app advertisement or announcement by the app’s developer as this introduces bias on the comments.</td>
</tr>
<tr>
<td></td>
<td>Sharing information about an app without expressing a view on the application features</td>
</tr>
<tr>
<td></td>
<td>Forums were not in English</td>
</tr>
</tbody>
</table>

| Date range | The last post on the thread was not more than two years before our search date (i.e. Thread dates before 17th November, 2013 are excluded). The search was performed on 17th November, 2015 and updated on 8th January, 2017 using the same criteria. |

4.3.3 Screening and data extraction

At this stage, in order to reduce extraction bias I invited a second reviewer to screen and extract the data independently; after which we compared and discussed the data. I screened the threads and assessed them against the inclusion criteria and exclusion criteria, with 30% checked by the second reviewer (EV) for quality control and 100% agreement was achieved.

For the included threads, I and the second reviewer (EV) extracted data using a piloted data extraction table under the headings of ‘app features’ and ‘feelings about features’. Only users’ perspectives about the features in the threads were extracted, comments from developers were excluded. People’s comments about a specific mobile product were mapped in a separate table. Any disagreements were resolved by discussion.

4.3.4 Data synthesis and analysis
A framework approach[104] was used in the data synthesis as I was interested to know what the patients’ feedbacks points on specific application features were.

- **Familiarisation with the threads:** I and the second reviewer (EV) read the included threads independently. We then compared our thoughts and impressions on the threads. We re-read and further discussed those threads involving unclear questions and answers, in order to come to a consensus.

- **Coding, developing and applying the analytical framework:** I and the second reviewer (EV) coded the threads in four rounds. We put our codes into the pilot table, which were compared and discussed after each round; any disagreements were resolved by discussion. For the framework, I used the same nine self-management supports identified in the systematic review, as follows: a) information about the patient’s condition and/or its management, b) monitoring of condition with feedback, c) provision of action plan, d) practical support for medication adherence, e) training/rehearsal to communicate with healthcare professionals, f) regular clinical review, g) provisions of equipment, h) training for practical self-management activities, and i) decision support for the healthcare professional. These nine criteria formed the first column of the ‘app features’ in the pilot table. ‘New app features’ commented on by patients, a point which was not one of the nine features in the systematic review, was added to the column. The threads were then imported to NVivo from the pilot table; the application’s features and people’s feelings were stored as nodes in NVivo for thematic analysis.

- **Charting the features and people’s opinions**
  a) Quantitative analysis: The numbers of responses on the features associated with people’s opinions were then exported from NVivo to Excel, and plotted on a bar chart for formatting.
  b) Qualitative analysis:
    i. If respondents mentioned a specific mobile technology product (app, smart device or website) their comments and the product’s key features were extracted into a separate table. The comments were mapped to gain an understanding of which product features were considered important.
ii. A framework thematic analysis was used. Application features were
categorised under themes, reviewed, re-categorised with reference to the
14 strategies for supporting self-management in the PRISMS[34] and
discussed iteratively with my main supervisor (HP) until agreements
were reached.

• Interpretation: The results were discussed within the multidisciplinary study team,
and also presented to interested participants at medical and computer science
conferences to explore any interesting ideas from the results.

4.4 Results

4.4.1 Characteristics of the included social discussion forums

37 social discussion forums, had 11 different foci, were identified by the key search
terms. They were:

i. specifically for asthma: Healthunlocked - Asthma UK and NHS choices[105],
   Personal Forum[106]
ii. specifically for other conditions: Breastcancercare[107], Diabetes Forum[108]
iii. general health: DailyStrength[109], WebMD[110], Everyday Health[111],
    MDjunction[112], eHealth forum[113], MedHelp[114], HealingWell[115],
    Patient.co[116], HealthBoards[117], Talkhealth[118], NetDoctor[119], Men’s
    Health Forum[120], Mental Health Forum[121], Carenity[122],
    PatientsLikeMe[123], HealthfulChat[124], Respiratory Futures[125], What
    Doctors Don't Tell You[126], The Guinea Pig Forum[127], No More Panic[128],
    CarersUK[129]
iv. running coaching: The RunningBug[130], Runner’s World[131]
v. allergy: AllergyUK[132]
vi. mental health: SAS social anxiety support[133]
vii. travel: Lonely Planet[134]
viii. app recommendation: iAPPs4You[135]
ix. smoking: Planet of the Vapes[136]
x. horse: Horse and Hound[137]
xi. multi topics such as entertainment, news and health: Tpoix[138], Reddit[139]

Of these 37 social discussion forums, nine were identified to have threads on asthma app/ smart devices.

4.4.2 Characteristics of the included threads

The identified threads, the screening process and the final numbers of threads included, are detailed in the flowchart (Figure 19). In total, 29 threads were included for analysis. They were extracted from nine social discussion forums; the majority being from Reddit. ‘Asthma’ and ‘app’ were not always the key words in the titles of the included threads.

The titles of the included threads are shown in Table 9.

![Flow chart for the included threads](image)
### Table 9 Titles of threads

<table>
<thead>
<tr>
<th>The titles of the threads</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Can a gadget for smartphones help people with asthma?”</td>
</tr>
<tr>
<td>“Can peak-flow-gadget help to control asthma?” attack?”</td>
</tr>
<tr>
<td>“Seeking asthma app to track peak flow. Do any incorporate a pedometer? What do you use?”</td>
</tr>
<tr>
<td>“Any good asthma management apps?”</td>
</tr>
<tr>
<td>“Asthma monitoring on phone, why is it not popular?”</td>
</tr>
<tr>
<td>“What would you like to see in an asthma app?”</td>
</tr>
<tr>
<td>“Motif app”</td>
</tr>
<tr>
<td>“Apps for recording peak flow (Apple)”</td>
</tr>
<tr>
<td>“Tracker app?”</td>
</tr>
<tr>
<td>“Asthma running help/app?”</td>
</tr>
<tr>
<td>“Beta App for Runners with Asthma”</td>
</tr>
<tr>
<td>“Couple of questions, re: asthma, lose it! app abd]and] weight loss@work”</td>
</tr>
<tr>
<td>“Air purifiers. Are they any good?”</td>
</tr>
<tr>
<td>“Personal pollution monitors to help with asthma”</td>
</tr>
<tr>
<td>“Newly diagnosed”</td>
</tr>
<tr>
<td>“Desperate – New to group”</td>
</tr>
<tr>
<td>“Hi. I’m new, nice to meet you 😊”</td>
</tr>
<tr>
<td>“I have my third chest infection in 12 months. My asthma’s come back. I quit[smoking]/ today”</td>
</tr>
<tr>
<td>“Respiration Problem”</td>
</tr>
<tr>
<td>“Scared”</td>
</tr>
<tr>
<td>“Asthma and Bronchiectasis seems worse in hot humid weather?”</td>
</tr>
<tr>
<td>“How to tell when Proventil HFA is “empty”?”</td>
</tr>
<tr>
<td>“Advair getting too expensive”</td>
</tr>
<tr>
<td>“I am trying to design the perfect metered dose inhaler. What should it have?”</td>
</tr>
<tr>
<td>“Hi, I was wondering what TRACKABLE possible environmental triggers exists in the asthma population?”</td>
</tr>
<tr>
<td>“inhaler user observation”</td>
</tr>
<tr>
<td>“Wheezy A tool for tracking asthma”</td>
</tr>
<tr>
<td>“I ran straight through [almost 7km straight in 47 minutes]”</td>
</tr>
<tr>
<td>“NSV – The towel wraps around me [successfully lost weight – the towel that the writer used, used to have a huge gap. Now the towel wraps around the writer with no gap]”</td>
</tr>
</tbody>
</table>

#### 4.1.1 Characteristics of the people whose posts were included

In total, 59 people with asthma expressed their opinions in the included threads. Only eight peoples’ comments were from a forum explicitly for asthma. (see Figure 19). People were identified as having asthma from their shared experience and self-introduction in the conversation. Of the 59 people with asthma, 57 gave feedback on specific application features and 16 mentioned the name of the existing technology (app,
smart device and website). Only two people with asthma talked about their experience using existing apps for weight watching without mentioning their feelings on the specific features of the app. They thought that losing weight would lead to better control of their asthma.

<table>
<thead>
<tr>
<th>Forum for general health</th>
<th>Forum for multi topics</th>
<th>Forum for running</th>
<th>Forum for asthma</th>
<th>Total no. of patients = 59</th>
</tr>
</thead>
<tbody>
<tr>
<td>eHealthForum(1)</td>
<td>dailystrength(3)</td>
<td>PatientLinkme(3)</td>
<td>Healthboards(1)</td>
<td>Reddit(33)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total no. = 14</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Key: x-axis was the types of the discussion forum; y axis was the total number of people with asthma. The number in bold are the total numbers of people with asthma from the discussion forum with the same theme. The names besides the bars are the names of the discussion forums.

Figure 20 The type of forum where the included people were from

The digital experience of the people whose posts were included varied. More than half of the people (34, 58%) stated that they had experience with digital tools, such as smartphone, app and excel spreadsheet. Fewer than 5% of the people used paper-based diaries (n=2) for self-management or had not used an app before (n=2). Others did not mention their prior experience of digital or paper-based self-management.

4.5 Application features

People with asthma generated a range of comments, from which 33 different features were identified that were then grouped into eight PRISMS components[34]. The eight components were: i) monitoring of condition with feedback, ii) practical support with adherence, iii) provision of equipment, iv) provision of easy access to advice or support...
when needed, v) training/rehearsal to communicate with healthcare professionals, vi) training for practical self-management activities, vii) training/rehearsal for everyday activities, viii) lifestyle advice and support. Figure 21 lists the features, the frequency of comments and the perceptions of the users of the social forums.
Features associated with response’s feelings

- **Lifestyle advice and supports**
  - Monitor and advice on weight loss for better asthma
  - Auto log running, steps data with pedometer for self-reference or future practice advice

- **Provision of equipment**
  - Electronic peak flow meter to log peakflow
  - Electronic MDI with dose taking log
  - Electronic MDI with low medicine warning

- **Practical support with adherence**
  - Reminder for inhaler

- **Training for everyday activities**
  - Cross ref. the environmental data with their asthma to decide everyday activities

- **Training/rehearsal to communicate with healthcare professionals**
  - Sharing data with GP/PM/carer

- **Provision of easy access to advice or support when needed**
  - Panic button to other asthma people who can help or 911
  - Monitor asthma condition, give emergency instruction & contact carer
  - Real time monitor and advice on the level of significant weather deviation
  - Real time monitor and advice on the level of indoor or outdoor pollutants with pollutant gadgets
  - Real time monitor and advice on the level of general asthma triggers (e.g. pollen)
  - Log symptoms manually and advice on the severity of asthma
  - Log peak flow manually and advice on the severity of asthma
  - Log the possible triggers manually for self-reference or future practice advice
  - Log dose taken manually for self-reference or future practice advice

- **Monitoring of condition with feedback**
  - Monitoring of condition with feedback, giving emergency instruction & contact carer
  - Log symptoms manually and advice on the severity of asthma
  - Log peak flow manually and advice on the severity of asthma
  - Log the possible triggers manually for self-reference or future practice advice
  - Log dose taken manually for self-reference or future practice advice

**Features mentioned once (Only negative mention in italics):** Training for practical self-management activities: reminder to check peak flow, sending weekly report to user themselves; Monitoring of condition with feedback; prescribed treatment record by urgent care or hospital, pop up, optional pollen alert, log diary, log spiro, log other health data, log no. of hospital or ED admission; Lifestyle advice and support: stress free (breathing), stop smoking, compare medication

**Figure 21 Respondents’ feedback on features**

- A: (+ve) experience, recommended to others, interested, what works from their experience
- B: (+ve) appreciated but worry
- C: (0) nth unique
- D: (-ve) doubt
- E: (-ve) experience or feeling not worth it or not interested in
4.6 Application features to support monitoring condition with feedback

Features in the ‘monitoring condition with feedback’ category were the most frequently discussed (81/106 feedbacks: 76.4%). Of all these features, logging peak flow, dose of drug taken, symptoms, real time pollutant monitor and advice were the top four features about which respondents felt positive.

1. logging peak flow manually and advice on the severity of asthma (n=18);
2. logging dose taken manually for self-reference or future healthcare professionals advice (n=11);
3. logging symptoms manually and advice on the severity of asthma (n=8);
4. real time monitor and advice on the level of indoor or outdoor pollutants with pollutant gadgets (n=8)

Below, I present the threads and their interpretation in the following format - “Thread” [Reviewer’s interpretation of posters’/respondents’ feeling about the feature (any contextual information)]

“I was looking for something to track my PEF-meter readings and other info like wheezing.” [Positive to log peak flow and symptom manually and advice on the severity of asthma (This person started the thread and asked for any good asthma management apps that could be recommend)]

“I’d like something simple. A counter app I can set to start with how many doses my inhaler is supposed to have, and then a way I can count down doses until I need to get a new inhaler.” [Positive to logging dose taken manually for self-reference or future healthcare professionals’ advice]

Of all the features in the monitoring condition with feedback category, smart devices such as a personal indoor monitor or outdoor air monitor, pedometer and electronic metered dose inhaler generated the most varied views from people with asthma.

“Good idea for future reference. I looked around online, saw one company that makes a gizmo that sits on top of an inhaler and counts down digitally...but that's 40 bucks and when battery dies after a year, it's done. Saw another option that's a hard carrying case that has a digital counter in the lid. About half the cost of the doser, but don't want another thing to buy and try to juggle in my purse.” [Appreciated but worry about cost]

“I am looking into creating personal pollution monitors for asthma patients. I'm always worried about what I am actually breathing when I go to parks and other
places outdoors. I am thinking something small with possibly an android app that can tell the pollution levels quickly and easily. I am wondering if this seem like something useful or worth pursuing?” [Doubt about the indoor or outdoor air monitor]

“None of those things [a list of inhaler features, including app, ergonomic and aesthetic, suggested by a designer] list of seem important to me. I just want it to work. Remaining puffs has already been implemented through a counter; I’d like to keep that.” [Nothing unique about the electronic MDI]

Other specific comments around ‘monitoring condition with feedback’ that were raised included concerns about data privacy when logging, storing and collecting health data with an app; and logging several aspects of health data in one place (any features that make life easier were regarded as ‘useful’). One person with asthma mentioned that she experienced difficulties on trying to log her children’s asthma diaries in a single account and would like to see an asthma app that could switch between accounts.

“My concern comes down to data/privacy and access to health information though. I am not comfortable with many health apps currently out because of what data I have to give them, how it is stored, and who may be gathering that data” [Data privacy concern]

“Be useful if you could combine the records for several things all in one place eg peak flow, spiro, weight etc…I personally would be very interested as it would make life a lot easier” [Make life easier (a response to a developer who asked if an app or smart device would be useful for people with asthma)]

“I do have [app’s name] on my phone but it doesn’t allow for separate accounts so I can input information for my kids in there. I have it in the "notes" section. Maybe that would be a handy thing for your [developer] app. I know I’m not the only parent with asthma.” [Difficulties with a single account]

4.6.1 Application features related to existing technology

20 people with asthma mentioned the names of specific technologies in the discussion. As the existing technology contained multiple features, patients’ feelings were for the whole app or smart device or website, as opposed to a specific feature, the results were reported separately in Table 10.
<table>
<thead>
<tr>
<th>Smartphone app</th>
<th>Supporting services</th>
<th>Key application features</th>
<th>Example feedback from people with asthma</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Provision of action plan and monitoring condition with feedback</strong></td>
<td>Asthma action plan, monitoring different parameters related to the patient’s asthma such as peak flow, medication and feeling for self-reference and future practice’s advice.</td>
<td>&quot;[app’s name]...I use it and find it very helpful…very clever little app.&quot; [FORUM: patient.co]</td>
<td></td>
</tr>
<tr>
<td><strong>Monitoring condition with feedback</strong></td>
<td>Monitoring different parameters related to the patient’s asthma such as peak flow, medication and feeling for self-reference and future practice’s advice. Log reminder</td>
<td>&quot;I use both [app’s name A], and [app’s name B]. They both have things I like, but if I had to choose, I prefer [app’s name A]. It has more options, such as making a weekly check, and you can even email your info to yourself or your doctor. The charts are nice too. You also can set reminders to check peak flow, and you can enter what meds you take when. Unfortunately they do not use a pedometer.&quot; [FORUM: reddit]</td>
<td></td>
</tr>
<tr>
<td><strong>Real time monitor and advice on the level of humidity</strong></td>
<td>&quot;I have a humistat in house to track humidity levels and watch [app’s name C] to be aware, I find its worth keeping tabs on weather conditions daily so as to minimize infections and flarups.&quot; [FORUM: patient.co]</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Lifestyle advice and support</strong></td>
<td>Running coaching</td>
<td>Today, I ran for almost 7km straight in 47 minutes. Started my [app’s name], and didn’t stop running until I heard “Mission Completed”…I had joint problems and was diagnosed with asthma… The day after my boyfriend's birthday (2 weeks after mine), I started working out. Then I decided that I was going to try running…TL;DR I ran farther(further) than I ever have without stopping. And it felt GLORIOUS!!&quot; [FORUM: reddit]</td>
<td></td>
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<td></td>
<td>Weight watching</td>
<td>“I have the [app’s name] app on my phone for weight loss…I have pretty bad asthma, &quot;exercise induced&quot;, and while I used it for an excuse not to exercise…I’m really hoping that, as I lose weight, I’ll be able to control it better…[FORUM: reddit]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Price comparison to dose</td>
<td>&quot;I seen the ad on tv at 4 am and decided to try it...my drug costs went from $1000 a month to under $200. It is called [app’s name]. You can go to GoodRx.com and get a hard card to but that wont tell you the price...or be the latest code...I just LOVE that APP!!!&quot; [FORUM: patientlikeme]</td>
<td></td>
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<tr>
<td><strong>Smart device</strong></td>
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<td>---------------------------------</td>
<td>---------------------------------</td>
<td></td>
</tr>
<tr>
<td><strong>Type</strong></td>
<td><strong>Key features</strong></td>
<td><strong>Example feedbacks from people with asthma</strong></td>
<td></td>
</tr>
</tbody>
</table>
| Monitoring condition with feedback | Measure peak flow, built in system to counter check the data reliability, plotting data on green, yellow and red zone, log medication, symptoms and triggers, set triggers alerts, reminder for medication, share data with professionals, Indoor air quality monitor | **"So I know [gadget's name] allows you to track "custom" metrics, so I guess you could set one up as Peak Flow. It won't do analysis, but it could be a good diary if you also want to track steps (but then you need to get a [gadget's name]...womp."** (A reply to the person who was looking for an app to track peak flow readings, medication and hoped to have a pedometer incorporated) [FORUM: reddit]  
**"I'm looking for a very similar thing and I've been seeing this floating around Reddit...could be what you're looking for! [gadget's website] (A reply to the person who were looking for an app to track peak flow readings, medication and hopefully a pedometer incorporated) [FORUM: reddit]**  
:"I had a respiration problem because of the dust particles. I started using a product named [gadget's name] and it works great. It shows the status of my environment and keep me away from the dust particles and I am free now. It just update the information in my smartphone as well as my tablet and I feel that am protected. It is just amazing." [FORUM: ehealthforum] |

| **Website/Blog** |
|-----------------|---------------------------------|---------------------------------|
| **Type** | **Existing technology in the market** | **Type** |
| Monitoring condition with feedback | Provide real time concentration and news on indoor and outdoor pollutant, enable discussion and feedbacks in the forum | **"I just found out about this smart phone based service being launched out of the NY area for runners with asthma. The upcoming (free) Beta sends daily personalized forecasts for your asthma triggers. Could be interesting to try out. [website URL] uses credible clinical and sports expertise to bring elite athlete level rigor to your diagnosed asthma condition for better asthma control, and enabling your best performance."** [FORUM: reddit] |
| Lifestyle advice and support | Provide information and news related to cycling, provide forum to connect with different users | **"You mentioned that you are into your cycling. Can I recommend that you take a look at The [web's name]? The communities on these two sites are brilliant at keeping you motivated." (This is a reply to advice a cycling website to another people with asthma because she thought exercise such as running would be good for asthma control) [forum: running bug] |
| Lifestyle advice and support | Author shares personal experience on running with asthma and readers feedback their thoughts on the threads. | **"I have asthma as well...This blog has a lot of helpful information [blog URL] (This is a reply to advice required for resources to help asthmatic train for their running goals) [FORUM: runner's world]"** |
4.6.2 Application features to provide lifestyle advice and support

15 people with asthma mentioned fitness and health features which were not usually included in an asthma app. These features were running coaching (n=6), weight watching (n=6), tracking activity (n=1), quitting smoking (n=1), logging health data such as exercise, hours slept and food (n=1). Of the 15 people, ten thought it was useful to combine these features with other asthma monitoring features or were looking for an app with these features. One person doubted if an asthma app with running coaching could be helpful for all people because asthma was a condition unique to each individual. People who mentioned running coaching were all frequent runners with asthma; they all thought exercise was good for asthma, including two who described themselves as having exercise-induced asthma.

“I’ve read that running helps improve the lung function & that running with asthma...But haven’t found any app that really helps an asthmatic track & improve their endurance training!...So I was wondering if others with asthma have used any specific resources (online sites, mobile apps, magazines etc etc) to help them train for their running goals?” [Positive to running coaching]

“What affects one person and works and doesn’t work for one person often has nothing to do with another person’s circumstances. For that reason, I wonder how an app could possibly be useful to all asthmatics.” [Doubt about running coaching]

Of the six people who mentioned weight watching, three people were positive about combining logging their weight and their asthma in a single app while three others mentioned specific weight watching apps that they had used.

“I have pretty bad asthma, "exercise induced", and while I used it for an excuse not to exercise, I’m finding now that I’m trying that it is genuinely a bit more of an issue than I had thought. I’m really hoping that, as I lose weight, I’ll be able to control it better, but until then, I was wondering if anyone has suggestions?” [Positive to losing weight]

One person with asthma, was looking for the best app to help quit smoke.

“I have asthma...I know this is caused by the smoking, or the smoking aggravates the cough caused by talking on the phone all day every day. So
this is me, I quit... what’s the best stop smoking App? (for android)”
[Positive to quitting smoke]

4.6.3 Application features related to self-management

Education, ownership of an action plan which advises people how to adjust their treatment, and regular professional/carer support are the crucial components of effective asthma self-management[24]. None of the people who posted comments discussed features about information about asthma and its management. No-one explicitly mentioned action plans or using self-monitoring data to adjust medication by themselves, although people frequently discussed the features of ‘self-monitoring’ and receiving ‘support from healthcare professionals’.

“if you have an[a] smart phone there is an app called [the app’s name] that I use. You can log symptoms, triggers, when you use your pro-air, Peak Flow Reading, etc. You can also send yourself a weekly report which I love.”
[Positive to logging trigger, symptoms, peak flow and sent weekly report to themselves]

“Can you also make it iOS compatible? I’d pay good money to have a more convenient way to track meds than my little snoopy notebook”
[Positive to logging medication - a developer mentioned they were developing an android for asthma diary to log medication and the person with asthma posted this response]

“I’ve never used an asthma app...But if I had to imagine I were using one, it would do the following:... Sends information in an eMail to my pulmonologist...”[Positive to professional support]

There was one person who recommended an app[140] endorsed by Asthma New Zealand, which incorporates an action plan and other monitoring features; other respondents indicated that they were ‘very interested’ in using this app.

“What is the app called please would be very interested in this please reply asap [as soon as possible]” [response A: an enquiry to the previous response who mentioned that there was an app by Asthma New Zealand which combined several records in one place]

“[The app’s name] It's a free iPhone app from the iTunes NZ store. It's been developed by the NZ Asthma Federation to try and help teens/younger asthmatics to keep track/record of their asthma symptoms, it also has a built in reminder to tell them when to use their inhaler. I use it and find it very
helpful, can also show to your Dr or even email a report to their office, very clever little app.” [response B: replied to response A].

There were another seven people who discussed an app prototype with an action plan. They discussed the monitoring features such as logging peak flow and two of them mentioned they used another app which also incorporated an action plan and other monitoring features. However, none of them explicitly discussed the action plan feature in the app.

“Has anyone signed up the [The app’s name] app. Loving it simple features. To find the link go to Asthma UK Facebook page and click on it. They want people with asthma to try out the app. Especially love the place for recording peak flow and diary entry.” [person A start the discussion in the forum]

“I also use [Another app’s name] app. That graphs it [the peak flow].” [Response B: replied to person A]

4.6.4 Application features related to emerging technology

Comments about using environmental surveillance to detect and display the concentration of triggers, enabling people to cross reference to their asthma control were all positive.

“I would want the ability to graph my peak flows with a decent level of detail. Track medication taken and the ability to print out and cross reference data points. Ideally to weather conditions like temperature, humidity and air quality.”
[Positive to cross reference with environmental factors]

Responses related to smart devices such as electronic metered dose inhalers, pedometers and indoor air monitors connected with smartphone apps varied. Of 14 responses in which a smart device was mentioned, eight were positive about using the device to auto log peak flow, running, steps, indoor triggers, and medication use.

“The only feature that would really benefit me would be a way to track when I took it, maybe interfaced with smart phones.”
[Positive to smart device: electronic metered dose inhaler – this was a response to a list of inhaler features, including app, ergonomic and aesthetic, suggested by a designer at the beginning of the threat]

“I’m after an app where I can track my peak flow readings, my medication intake and hopefully have a pedometer incorporated. Does such a thing exist?” [Positive to smart device: pedometer]
"I had a respiration problem because of the dust particles. I started using a product named [the smart device's name] and it works great... It just update the information in my smartphone as well as my tablet and I feel that am protected. It is just amazing." [Positive to smart device: indoor monitor]

One person felt the smart metered dose inhaler with features of dose-taking log, peak flow log, air quality sensor and reminder was no different from a common metered dose inhaler. Four responses emphasised that they just “want it (the inhaler) to work”. Two responders who appreciated using a smart device were also worried about the high cost and data privacy issues.

“None of those things [a list of inhaler features, including app, ergonomic and aesthetic, suggested by a designer] seem important to me. I just want it to work. Remaining puffs has already been implemented through a counter; I'd like to keep that. Otherwise, my only criteria is that it work.” [Just want the inhaler to work. response A]

“Not really interested in any of those things. Like [response A] said I just want it to work and not cost a fortune.”
[Just want the inhaler to work and worry about the cost. Response B - commented on the response A]

“I've been reading this thread and also the original, and I've really felt the same as most people in that we just need something that works and isn't a million bucks...My concern comes down to data/privacy and access to health information though.”
[Worried about data privacy. Response C- commented on the same thread of response A and B]

4.7 Discussion

4.7.1 Summary of findings

Online social discussion forum review provided a real-time capture of what mobile app features that people valued in a natural setting. Eight categories of self-management support: i) monitoring of condition with feedback, ii) practical support with adherence, iii) provision of equipment, iv) provision of easy access to advice or support when needed, v) training/rehearsal to communicate with healthcare professionals, vi) training for practical self-management activities, vii) training/rehearsal for everyday activities, viii) lifestyle advice and support, were discussed by people with asthma in eight social forums during the period (November 2013-
Monitoring of asthma via an app with feedback features were widely discussed and valued by people with the condition. For example:

- log peak flow manually and advice on the severity of asthma
- logging dose taken manually for self-reference or future healthcare professionals advice
- logging symptoms manually and advice on the severity of asthma
- real time monitoring and advice on the level of indoor or outdoor pollutants with gadgets)

Forums for general health and multiple topics which contained discussions on health, entertainment and technology, were able to reach a wider population of audience with different interests and so formed the majority of people in the included threads. No-one explicitly commented on features related to information about asthma and its management, action plans or using logged data to adjust their medication for self-management. However, seven people explicitly discussed apps known to incorporate an action plan, though the feature people highlighted and recommended to others was being able to send information to their doctor. Lifestyle advice and support features, such as running coaching, weight loss and quitting smoking, were rarely incorporated in the asthma app, but were features welcomed by some people with asthma. Smart devices provoked a range of responses from positive to adverse. In general, people with asthma would like to log all their health data in one app as that would make their life easier. Multi-account usage was suggested by a user who was asthmatic herself as well as caring for their child with asthma.

4.7.2 Strengths and limitations

This review examined specific mobile apps’ features which people valued, as opposed to the general characteristics of an app, thereby informing the future development of an asthma self-management app. However, the review has some limitations. Firstly, body language, facial expression and tone, which could be captured in qualitative interview, could not be captured from questions and responses in online social discussion forums. We did not post follow up questions to ask for explanations as we wanted to collect people opinions in a natural environment without contributing disturbance or leading the discussions. It is evident this proviso
prevented us from further exploring more nuanced opinions. On the other hand, the data we collected were freely expressed in an ‘open’ environment compared to an interview for a research project which addresses a specific research agenda.

Secondly, the numbers of comments are not large enough to perform a quantitative analysis, though qualitative analysis provides insights into which features people want. Thirdly, the opinions we collected were from ‘posters’ (people who communicate their experience to others) and omitted the ‘lurker’ (those who read the content but do not post their opinions in the forum)[141]. The results may not include all the features that would be valuable to all people with asthma. Importantly the features discussed were generally components of existing self-management apps. Further research will be needed to identify novel features that may motivate people to change their behaviour and adopt asthma self-management in an app. However, our list of features, provided list of specific app’s features that people valued, opposed to general description of app, may be a useful starting point for discussing and developing a app prototype.

Lastly, due to resources and time constraints, only a single review at the initial screening stage was performed, though we used quality control processes and checked all data extraction in discussion with a second reviewer in order to minimise error and bias.

4.7.3 Interpretation in relation to published literature
Patients’ discussions on social forums were limited to the common features that presented on the past and current apps in the market. Huckvale provided asthma app reviews in 2011 and 2013[44][45]. Self-monitoring such as logging peak flow, symptoms, and medication were the common features on asthma apps in these reviews and were the features mostly widely discussed on the social forums accessed for my findings. Another most discussed feature in my review was about a gadget to detect indoor air quality (IAQ), which Huckvale’s review did not refer to. Also, such a gadget did not appear in my first search on the 17th November, 2015. The increase in discussion on this topic, may be because IAQ gadgets were becoming more affordable to patients around 2016, more patients were able to buy one and try, therefore, more patients discussed the issue in 2017. This underlies the ability of social forum analysis to detect rapid change in opinions.
4.7.4 Implication for the next steps

The findings suggested a flexible app is needed to cater for different ‘wants’ from patients. The core features of the asthma app are to support a patient’s monitoring with feedback (basic monitoring parameters: logs peak flow, medication usage and symptoms) and to incorporate an action plan. Connection with smart devices, such as a smart metered dose inhaler, pedometers and indoor air monitors are ‘eye catching’ features for some patients. However, the ‘unreliability’ of those devices, especially the smart dose inhaler discouraged some patients. Lifestyle advice and supports such as weight loss and running coach could be optional features to attract some patients. The next step is to identify novel features that may motivate people to change their behaviour and adopt asthma self-management in an app.

**Conclusion from online social discussion forum analysis**

The majority of comments posted on social forums by people with asthma focus on self-monitoring rather than self-management. Comments on asthma apps are few. No-one explicitly mentioned an action plan; although some were positive about apps known to include action plans. However, a number of features of mobile apps associated with supported self-management such as monitoring peak flows, symptoms, medication use, monitoring indoor or outdoor triggers and pollutants, receiving feedback or advice for further actions on their asthma were accepted by people with asthma. Specific features such as running coaching, weight loss and quitting smoke were welcomed by a few people, but were not necessarily wanted by the general population with asthma. People with asthma were aware of smart devices and apps designed to help them; however, the scope of their adoption remains unknown. Importantly the features discussed were generally components of existing self-management apps. Further research will be needed to identify novel features that may motivate people to change their behaviour and adopt asthma self-management in an app.
Chapter 5  (Phase 1) Technology/marketing perspective: To identify features of existing mobile apps which aim to support asthma self-management

Having looked previously at what patients had discussed in the online social discussion forum, in this section, I explore what asthma self-management features were available in the app stores and which features seemed to attract patients to download the app. App stores[143,144] provide rich data such as the numbers of downloads, app descriptions, and star rating. In research, Huckvale’s systematic assessment on asthma apps[44, 45] provided information on features of the available self-management apps on the market from 2011 to 2013, however, he did not associate those features with patient’s preferences. Therefore, I decided to conduct a review to explore the features and their association with attractiveness, as inferred from download statistics.

5.1 Rationale for the methodology of this study

Initially, I considered a published app assessment tool, Mobile App Rating Scale (MARS)[142], to review the asthma apps because a) it provided an objective evaluation scoring system to assess apps from engagement, functionality, aesthetics, information perspectives, b) it was a validated by research which was associated with the star rating and c) it provided robust training materials online. The rating questions are presented in Appendix 6. As a preliminary exercise, I assessed five
asthma apps with a reader(MW) in the Design Informatics School of our University and the second reviewer. However, after discussions regarding the preliminary scoring (see Appendix 7), I decided not to continuous use MARS[142] to assess. There were two reasons:

1. **Subjective nature of the MARS scoring[142]**

Some of the scoring questions (see Table 12) were highly subjective to reviewers which made it difficult to reach a consensus. For example, they asked reviewers to score if the app was ‘fun’, interesting to use’, ‘easy to learn’ and ‘looking good’; parameters that are highly subjective. For example, some users thought an asthma app with game elements was ‘interesting to use’, however, others may think a game was something for children and it would hold no interest at all for them. Therefore, it was difficult to score these questions reliably.

| Q1. [Engagement] Entertainment: Is the app fun/entertaining to use? Does it use any strategies to increase engagement through entertainment (e.g. through gamification)? |
| Q2. [Engagement] Interest: Is the app interesting to use? Does it use any strategies to increase engagement by presenting its content in an interesting way? |
| Q7. [Functionality] Ease of use: How easy is it to learn how to use the app; how clear are the menu labels/icons and instructions? |

Table 12 The scoring questions

2. **Items omitted from the score**

Secondly, there are several important features that are not covered in the functionality section, as follows: a) language, b) security and data privacy, c) network dependence, d) data validation and e) interoperability of the app.

a. Language: did the app use natural language at the correct reading level? For example “see your GP if your symptoms are getting worse” vs “consult your medical advisor in the event of deterioration.

b. Data security and privacy: did the app use VPN to protect sensitive data? How did the app store a patient’s log? Did the app provide a channel for in app ‘phishing”?

c. Network dependence: can the user use the app without mobile internet (native app VS web app)?
d. Data validation: does the app alert users to unreasonable/unlikely inputs (for example, includes upper and lower range setting in the input box for peak flow)?

e. Interoperability: how easy is it for the app to connect with third party devices or platforms (for example: a smart watch or the medical practice’s database)?

Because of these omissions, I decided not to use MARS[142] to assess the apps.

*Statistics to reflect attractiveness*

The star rating system, users’ reviews and download rates that are available from the apps’ stores are considered to be parameters which assess, or at least indicate, an apps’ attractiveness. However, star ratings and users’ reviews are subjective data from random reviewers and may not be representative of other users who did not post comments. However, it is acknowledged that some users look at such reviews to make decisions when downloading an app. A more objective parameter is an app’s download rate, which can be seen as an indication of the attractiveness of the app; although download statistics are not available from the Apple app store[144]. Also, some users may stop using the app immediately when they find the app does not offer what they expected. Because there were only two included apps using Apple iOS of the total 25 included app (see below section 5.4.1). In this review I wanted to explore the apps’ attractive features, as opposed to its adherence features; therefore I decided to review the asthma apps by using their download rates. In the following sections, I will discuss the review.

**5.2  Aim of this app review**

The primary interest for this app review was to explore the download rate associated with different features of the asthma apps in the market. In additional to this primary interest, I wished to discover the common features of apps that were available for patients and how they related to the PRISMS taxonomy[33].

**5.3  Method**

5.3.1  App search and selection

I adopted systematic review methodology to search and select apps. Local searches were performed in the Google play store[143] and Apple app store[144] for Android and iOS apps respectively because these were the most used platforms for app
downloads. I used online data crawling platforms\[145,146\] to extract app descriptions associated with different search terms, in order to decide the search terms in the local search as well as the search strategy. Data crawling platforms are a web tool to turn website information into data to a spreadsheet. ‘Asthma’ AND (‘log*’ OR ‘monitor*’ OR ‘management’) were used as the key search terms for the apps. The search was restricted to the apps available in the UK. Identified apps were assessed against the inclusion and exclusion criteria in Table 11.

Table 11 Search strategy

<table>
<thead>
<tr>
<th>Inclusion criteria</th>
<th>Exclusion criteria</th>
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<tbody>
<tr>
<td>• Smartphone OR tablet apps</td>
<td>• Could not be downloaded in UK due to country restrictions</td>
</tr>
<tr>
<td>• Available in Google Play and iOS app store</td>
<td>• Could not be used / opened due to technical problems after 3 attempts</td>
</tr>
<tr>
<td>• Apps claiming use for on-going facilitation of asthma self-management with features of the nine themes summarised in the systematic review: a) information about condition and/or its management, b) monitoring of condition with feedback, c) provision of action plan, d) practical supports for medication adherence, e) training/rehearsal to communicate with healthcare professionals, f) regular consultation, g) provision of equipment, h) training for practical self-management activities and i) decision support for the healthcare professional; and one of the features had to be an asthma diary or action plan. This is because an asthma diary logged by patients and asthma action plan given by practices are the core to initiating patient and healthcare professionals' discussions on asthma self-management.</td>
<td>• Required authorisation from clinic or hospital, therefore, unavailable to access</td>
</tr>
<tr>
<td>• Written in English</td>
<td>• The app’s last update is not more than one year prior to the search date</td>
</tr>
<tr>
<td>• Not targeted for children</td>
<td>• First search: 01st April, 2014 to 01st April, 2015</td>
</tr>
<tr>
<td>• At least 1 user reviews available in order to reduce the chance of including random ‘testing’ apps</td>
<td>• Update search: 11st April, 2016 to 11st April, 2017.</td>
</tr>
<tr>
<td>• The app’s last update is not more than one year prior to the search date</td>
<td>• This is to make sure the reviewed app was the most updated version.</td>
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</table>

Page 106
5.3.2 Screening, data extraction and data synthesis

I screened the apps and assessed each example against the inclusion and exclusion criteria, with ten apps checked by a second reviewer (KF) for quality control; 100% agreement was achieved.

For the included apps, I extracted their features and download rate into a table. I downloaded and tried out the features in the included apps, reviewed the app’s description and numbers of downloads on the app stores[143,144] to complete the table. The application features were grouped using the PRISMS taxonomy[33]. In addition, I filled in the numbers of the most downloaded apps which contained those features in the taxonomy.

5.4 Results

5.4.1 Characteristics of the included apps
The identified apps, the screening process and final numbers of apps included, were detailed in the flowchart (Figure 23). 15 apps were included in the initial review, 10 apps were added after the updated review. Of the total 25 apps[147-171], two apps[157, 158] were only available from the Apple Google play store[144], 23[147-156, 159-171]were available on both Apple app store[144] and the Android Google play store[143]. The app’s features and the numbers of downloads are presented in Table 12. It should be noted that data for the two apps[157, 158] from the Apple app store[144] are missing because the store did not provide the number of downloads.

.
Included apps (n=23):
- AsthmaMD (n=2)
- EPIwAsthma (n=2)
- Asthma tracker: Asthma Tracker, MyAsthma UK, RASTH Inhale, Asthma Plus, My Asthma Score (n=5)
- Peak flow tracker: PeakFlow, myPeakFlow, AsthmaPlot, Peak flow manager. Sporolab, FEEno. Breathcount (n=7)
- Medication tracker: CareTRX Asthma & COPD journal, MyTherapy (n=2)
- General health app: Health Tracking - Four Health, Continuous Care, Allergy Monitor, Allergy Diary by MACTIA, ZedlyHealth, Simple symptoms, mySymptoms, Food (n=7)
Figure 23 Flow chart for the included app, categorised as ‘self-management app’, ‘asthma tracker app’, ‘peak flow tracker app’, ‘medication tracker app’, ‘general health app’

Table 12 summary of app’s features and their numbers of downloads on 07/04/2016 and 11/04/2017
The columns are the different apps, grouped by key features, the rows are the features grouped by themes (systematic review and social discussion forum analysis). The shaded column feature the most downloaded apps, where the downloads exceed 100,000.

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<tr>
<th>Type</th>
<th>Self-management</th>
<th>Asthma tracker</th>
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<tbody>
<tr>
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<td></td>
<td>Asthma Tracker</td>
<td>My Asthma UK</td>
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<td>Action plan</td>
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</tr>
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<td>Warning based on peak flow</td>
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Page 109
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</table>
5.4.2 Application features

Of the 25 apps[147-171], 46 key features were identified, I grouped them into eight common themes i) information about asthma; ii) action plan; iii) monitoring condition with feedback; iv) practical support with adherence; v) provision of equipment; vi) training or rehearsal to communicate with healthcare professional; vii) training for practical self-management activities; and viii) lifestyle advice and support. Self-monitoring and sharing records with practices or carers were the selected apps’ commonest application features. The monitored asthma-related data could be either manually entered or automatically transferred by electronic metered dose inhaler and electronic peak flow meter. Table 12 lists these features in detail. 13 different types of data were available for monitoring, these included: medication intake; hospital or A&E admission; asthma trigger; peak flow; perception of asthma control on three-point scale; perception of asthma control on continuous scale – good to bad, perception of asthma control on continuous bar - ‘Not at all’, ‘bothersome’, ‘extremely bothersome, asthma control test(ACT), asthma symptoms, eyes and nasal symptoms, activity, mood and food. Only two apps provided an action plan. Of the total 25 apps[147-171]:

- eight[152,154, 157, 160,161, 168,169,171] were for general health conditions,
- 17[147-151,153,155-159,162-167,170] were explicitly for asthma,
- two[151,167] were asthma self-management apps incorporating an action plan,
- six[147,156,158,159,164,165] were tracker apps for asthma-related or lifestyle data such as peak flow, symptoms, medication intake, asthma control test, food, exercise etc,
- seven[148,149,153,155,162,163,166] were tracker apps explicitly for peak flow and
- two[150,170] were tracker apps explicitly for medication intake.

5.4.3 Numbers of downloads

The numbers of downloads ranged from 1-5 to 100,000 - 500,000. These numbers provide snapshots on the included app’s adoption on 07/04/2016 and 11/04/2017. The large variations in the download numbers were thought to be due to the attractiveness of the apps as well as a) the time duration that they had been published
on the app’s store[143] and b) the download cost. One app[162] had 1-5 numbers of downloads, it costs £2.49, was on its 1.0.2 version, and was found in the updated search so presumably it was published very recently. Four apps[151,154,156,170] were free, had 100,000 - 500,000 numbers of downloads, and had been published for at least a year.

5.4.4 Application features associated with numbers of downloads

Self-monitoring, as opposed to self-management with action plan, was one of the most common features in the apps. Of the four most downloaded apps, only one included an asthma action plan. The app did not specify that the action plan in the app should be filled in by a GP or asthma nurse, however, it requested the user to confirm that the data entered on the app were issued by a physician. Also, it did not advise that increasing ICS or starting a steroid course depended on a patient’s condition. An app which had self-monitoring features or an action plan hit the highest numbers of downloads of 100,000 - 500,000. However, the app with an action plan and without monitoring features had a lower numbers of downloads[167] (51-100) than the one with monitoring feature for triggers, peak flow and symptoms only[151] (100,000 - 500,000).

Of the four most downloaded apps, two of the apps[151,170] mentioned the data collected by those apps were used for research purposes. Half of the highest downloaded apps[156,151] were explicitly for asthma, and half[154,170] were for general purposes. Logging peak flow and sharing records with the practice or the users’ health carers were common features. However, logging peak flow was not the only feature in most of the apps[151,154,156,170], other logging parameters available were a) medication use, b) symptoms, c) ACT, d) mood and activity. Medication reminders were provided by three of the apps[151,154,156,170] with one able to transfer an alarm to a smartwatch[170]. Specific features on the apps were:

- giving advice on medication adjustment by action plan and suggested asthma conditions by peak flow on a three zoned graph[151];
- connection to Google fit to log daily activity[156];
- storing medication information by scanned barcode[170];
- providing a virtual clinic such as real time healthcare professionals consultation and monitoring[154].
5.4.5 Taxonomy of self-management support

The most downloaded asthma apps support six of the 14 PRISMS strategies[33] (see Table 13). They focus on supporting monitoring with feedback such as logging asthma symptoms and peak flows for self-referencing or sharing with practices. However, they were less focused on supporting self-management. Only one of the most downloaded apps provided an asthma action plan. This result shows that it is technically feasible for apps to offer features to support self-management, however, in general most failed to move on from self-monitoring to self-management.

There are various possible reasons for this lack of focus on a patient’s self-management. For example, a) technology developers might not know about what was involved in asthma self-management and could have overlooked important features, b) the financial payback of developing a self-management app was not promising and therefore, they gave up, c) possibly self-management apps could fall into the ‘medical device’ category, meaning that further resources are needed to obtain approvals for CE marking before launching to the market. Further research is needed to explore the impact of these possible barriers on asthma patients’ self-management app development.

The first two barriers involved internal decisions made by the technology companies which needed to be explored individually by cases. Proprietary and sensitive data such as their company’s strategic planning on payback margin, the download rate or purchase rate of their previous apps or their competitor’s apps were needed to further explore those barriers. The third legislative barrier was external to technology companies which it will be explored further in the later sections of this thesis.
Table 13 The 14 PRISMS taxonomy components and the features extracted from the existing apps on Apple and Android stores

(Key: 😊 one of the most downloaded asthma apps; four in total.)

<table>
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<th>Taxonomy item</th>
<th>Application features</th>
<th>Features in the four most downloaded apps</th>
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<td>Not provided in the apps.</td>
</tr>
<tr>
<td>Information about available resources</td>
<td>Not provided in the apps.</td>
<td>Not provided in the apps.</td>
</tr>
<tr>
<td>Provision of/agreement on specific clinical action plans and/or rescue medication</td>
<td>Asthma action plan</td>
<td>😊</td>
</tr>
<tr>
<td>Regular clinical review</td>
<td>Not provided in the apps.</td>
<td>Not provided in the apps.</td>
</tr>
<tr>
<td>Monitoring of condition with feedback</td>
<td>Log peak flow, log asthma (e.g. triggers medications, symptoms, act, a&amp;e admission etc), show peak flow on graph only, show peak flow on map, zoned colour graph, show peak flow severity by words, show medication adherence and reason for missed medication, show symptom over food intake, warning based on peak flow, sharing record with practice/carers/family members</td>
<td>😊😊😊😊</td>
</tr>
<tr>
<td>Practical support with medication adherence</td>
<td>medication reminder</td>
<td>😊😊</td>
</tr>
<tr>
<td>Provision of equipment</td>
<td>Not provided in the apps.</td>
<td>Not provided in the apps.</td>
</tr>
<tr>
<td>Provision of easy access to advice or support when needed</td>
<td>Not provided in the apps.</td>
<td>Not provided in the apps.</td>
</tr>
<tr>
<td>Training/rehearsal to communicate with healthcare professionals</td>
<td>Sharing record with GP or asthma nurse</td>
<td>😊😊😊😊</td>
</tr>
<tr>
<td>Training/ rehearsal for everyday activities</td>
<td>Not provided in the apps.</td>
<td>Not provided in the apps.</td>
</tr>
<tr>
<td>Training for practical self-management activities</td>
<td>Personalised reminders/booking appointment, tracking reminder</td>
<td>😊</td>
</tr>
<tr>
<td>Training/ rehearsal for psychological strategies</td>
<td>Not provided in the apps.</td>
<td>Not provided in the apps.</td>
</tr>
<tr>
<td>Social support</td>
<td>Not provided in the apps.</td>
<td>Not provided in the apps.</td>
</tr>
<tr>
<td>Lifestyle advice and support</td>
<td>Log lifestyle (e.g. activity, mood, food) over asthma condition</td>
<td>😊</td>
</tr>
</tbody>
</table>
5.5 Discussion

5.5.1 Summary of findings
Eight categories (i. information about asthma; ii. action plan; iii. monitoring condition with feedback; iv. practical support with adherence; v. provision of equipment; vi. training or rehearsal to communicate with healthcare professional; vii. training for practical self-management activities; and viii. lifestyle advice and support) of features were available from Android and Apple during the period of 01st April, 2014 to 11st April, 2017. Common features were self-monitoring and sharing health records to practices and carers. Only two apps provided an action plan: one had the highest download numbers of 100,000 - 500,000[151], another one was 52-100[167]. For the apps with the highest numbers of downloads, peak flow logging and sharing records with healthcare professionals and carers were common features. Four specific features in the most downloaded apps were: i) an action plan[151], ii) transfer of activity data from Google fit[156], iii) storing medication information by scanning barcode[170] and iv) monitoring[154].

5.5.2 Strengths and limitations
The data explored here were for public reference and were up-to-date, though they may not be generalisable to the preferences of patients who did not download and/or use an asthma app. Other limitation were:

- Firstly, the numbers of downloads were not available to be extracted from the Apple app store[144], though only a small numbers (three out of the 25) were only available in the Apple app store[144].
- Secondly, the app’s launch date was not available on app’s stores[143, 144], the numbers of downloads were a snapshot result on the two particular review dates which resulted in incomparability across different emerging apps. However, extracting the features from the apps with a reasonable to highest download number (100,000 - 500,000) showed the potential features of apps that appeared to be attractive to patients.
- Thirdly, the features in the most downloaded apps were not necessarily used substantially, or even at all, by the patients; we just don’t know if the apps were used by the phone owner. A user may download the app because they
were free, their advertising was good as opposed to because they were good. Further research will be needed to evaluate the use of apps after downloading (adopting) and to identify the adherent features designed to support the asthma patient’s self-management.

- Lastly, service deployment and advertisement of the apps were not considered in the review. Further research will be needed to identify optimum methods of service deployment, and the most effective ways to promote the app.

5.5.3 Interpretation in relation to published literature

Only two apps contained an action plan, however, the numbers of downloads were different: one of these two apps had the highest download numbers of 100,000 - 500,000[151], the other had 52-100[167]. The difference could be due to a) their marketing duration on the app store[143], since the one with most downloads had been there for one year and the other only half a year b) their promotion on the use of data, the highest one claimed the app would collect data for research purposes and the other one did not claim any research purposes in app store description or on their website c) the difference in their features, the highest one allowed trigger, peak flow and symptoms logging and the other one had no data monitoring features.

Recently, another researcher used MARS[142] to assess asthma apps[50]. Their inclusion criteria were similar to mine, except they included all the apps that were designed specifically for asthma while we only included the asthma apps with self-management elements; also they additionally excluded apps which were less than less than 1000 downloads on the Google Play store or less than five reviews on the Apple app store. They had four reviewers to assess the included app with MARS[142]; however, the scoring deviations between different users were not reported. The result of their MARS[142] showed their included asthma app performed the worst in user engagement and the best in app functionality. I cross checked their final MARS[142] score with some of our included apps and found differences between our scores – for example, for an app, called Asthma MD[151], we scored it as performing worst in aesthetics (see Appendix 7). ‘Information’ was the category that we both agreed that the app performed the best. These differences
in opinion resonated with what the Reader in Informatics (MW), second reviewer (KF) and I had experienced when assessing the five apps.

5.5.4 Implications for the next step

This review provided specific features, as opposed to general characteristics of apps, of the most downloaded (adopted) apps, in order to inform future development of asthma self-management app.

**Conclusion from the app review**

Asthma self-management can be supported by current apps. The most downloaded apps were focused on self-monitoring, as opposed to self-management; only one of which offered an asthma action plan. Logging peak flow and sharing records with practices or their health carers were the commonest features in the most downloaded apps. Further study is needed to understand the barriers to moving apps from self-monitoring to self-management.
Chapter 6 (Phase 1) The legislative perspective: the legislative regulation of standalone apps for healthcare purposes

In this chapter, I will explain the stakeholder involvements in app development and the implications of the current guidelines in relation to asthma app development.

6.1 Stakeholders involved in the app process

Apps have potential use for both individuals and groups; they can raise the profile of companies, as well as provide healthcare benefits to patients. This potential value attracts different stakeholders, both professional and lay developers, to engage in the app’s creation. Different stakeholders hold different responsibilities in different stages in an app’s life cycle (see Figure 25).

From a legislative perspective, the legislative examiner (the MHRA) assesses whether the device falls into the category of a ‘medical device’ as defined in the Directives[46, 47, 48]. The device is assessed based on its intended purpose(s) as intended by the manufacturer. The app development group, made up of: a) app’s designer, b) funder, c) technical maintainer, d) service provider and e) service adopter, are responsible for designing, developing and maintaining the app. The legislative advisor is a middleman whose role is to communicate between the legislative examiner and the app’s development group. The advisor interprets the
directive[46,47,48] requirement to the development group and provides advice relevant to the necessary governance applications.

**Legend**

This grey circle implies stakeholder's engagement point of the app's life cycle. The number inside refers to the stakeholders listed below.

1. End user: individual who uses the app e.g. patient, clinician, NHS. For a research project, the earliest engagement point is in the planning stage whereas for commercial project, the engagement point is usually at the release stage.
2. Funder: pays for the app’s development e.g. individual, academy institute, charity organisation, government
3. App designer: provides the design of the app e.g. individual designer, researcher, private company, app’s service provider
4. Legislative and research governance advisor: provides advice to the development group on whether the device is likely to be classified as a ‘medical device’ and advice about governance applications for any research work on ‘medical devices’ e.g. university sponsor, NHS, notified bodies (Amtac Certification Services Ltd, BSI Healthcare, Lloyd’s Register Quality Assurance Ltd, SGS United Kingdom Ltd, UL International (UK) Ltd).
5. App coder: puts the design into an app (‘codes’ the app) e.g. individual programmer, researcher, private company, app’s service provider
6. Legislative examiner: assesses the safety, quality and effectiveness of the app for approval application e.g. The UK MHRA
7. App technical maintainer: individual/organisation which maintains the accuracy of the app e.g. individual programmer, researcher, app’s service provider
8. Service provider: individual/organisation which provides the app to the user and receives profit if it is a paid app e.g. charity organisation, private company, NHS
9. Service adopter: individual/organisation which uses the app to support patient’s health decision e.g. clinician, NHS

Figure 25 Stakeholders’ involvements in the app’s life cycle
6.2 What are the implications of the current medical device legislation guidelines in relation to asthma app development?

The BTS/SIGN guidelines suggest education, asthma action plan and regular consultation are the core elements of an asthma self-management. An app is able to deliver features to support these three cores; for example, app can a) provide video links to educate patients with correct inhaler technique, b) include an asthma action plan and ‘pop up’ the action plan’s advice to patient based on their logged peak flow and symptoms, and c) can also to provide online video consultation.

From the legislative perspective, the medical device directives[46, 47, 48] use ‘intended purpose’ to define if an app is a ‘medical device’ and so would need to be specifically regulated as such. The MHRA published in August 2016[65] provided a clearer insight on the ‘intended purpose’ based on what features the app includes. ‘Monitoring of disease’ is one of the features that define that the app has a medical purpose. It further explained that if the app ‘simply replaces a written diary/log of symptoms that support consulting with the patient’s doctor’, it is unlikely to be classed as a ‘medical device’. However, for an app which aims to support the asthma action plan as recommended by the asthma guidelines[24] it is most likely to be classified as a ‘medical device’ because in addition to asking patient to log their peak flow and symptoms, it responds to the monitoring by providing clinical advice on the action to take. This explains why most of the asthma apps only provide the feature to log peak flow and symptoms, and do not move on to incorporate an action plan, despite extensive evidence that it is the action plan that is effective[172]. In contrast, if the app only ‘stores or transmits medical data without change’, it is defined as having ‘no medical purpose’.

However the distinction is not clear cut. If the app only includes the pdf, or another format that the patient cannot change, for an asthma action plan, would that be considered to be a ‘medical device’ or not? An app which provides a feature for patient medical education only is not a ‘medical device’. However, if the information includes an action plan the classification is less clear. This ambiguity is particularly worrying if the plan is interactive, with a change in symptoms triggering referral to an appropriate step of the action plan, such as advising the patient to increase treatment or start steroids. Therefore, if the app aims to support the three core
components of asthma self-management, it is likely to be classified for legal purposes as a ‘medical device’.

6.3 Implications for app development

For several reasons, current legislation and medicolegal concerns constitute a barrier to using digital technology to support self-management for asthma.

Time and resources investment

To be regulated as a ‘medical device’ implies more time and resources are needed for the app’s development. This could be a reason to halt the development of a self-management app. It can take a decade to produce the safety evidence required for legislative approval[55] by which the system is legacy; while no one knows if the system will be, or would have been, welcomed and adopted by patients. In the meantime, both time and resources have been invested. In contrast, if technology companies develop the app in countries without legislation, their initiative may require less investment. Apps can be sold across different countries. Developers can launch their apps in the app stores where the countries do not have the regulations, and patients can still download their apps by different methods such as amending the country’s setting or use different sim cards. Ideally the regulation is launched worldwide at the same time. However, it is always a challenge to reach consensus on harmonising the law across countries. Therefore, the legislation become a catalyst to push developers to think of alternative ways to develop an app, as opposed to making sure the developers make the app in the ways that the regulatory bodies wish them to. Alternatively, the simplest solution for some developers is not to develop an app with potential features that would classify it as a ‘medical device’.

Approval invalidation in a rapid technology development cycle

Technology development cycles typically launch updates every few months which invalidate existing approvals. Technology developments such as apps are not a one-off cycle (see Figure 4). Such development responds promptly to feedback from users and changes features iteratively in order to eliminate bugs and maintain the users’ satisfaction. However, approvals usually need at least a year before they are granted, which does not match the technology development cycle. Approvals become invalid if the app has already changed its features. This dissonance, caused
by the un-matching cycles, increases the challenges which need to be overcome by the app developers.

Medicolegal concerns

In the development of self-management apps, different stakeholders are involved (see Figure 25). The technology developer is not necessarily the company which owns, designs and produces the app. Developers might only provide specific technology service support to the app such as a) bespoke coding services, b) app platform service, c) security service or d) database maintenance. However, developers play a key role to make the app useable and available to patients.

Under the ‘medical device’ directive, the legal responsibility for the device is taken by the ‘manufacturer’. The ‘manufacturer’ is defined as ‘the natural or legal person with responsibility for the design, manufacture, packaging and labelling of a device before it is placed on the market under his own name, regardless of whether these operations are carried out by that person himself or his behalf of a third party.’[46, article 21]. The directive further adds ‘the manufacturers also apply to the natural or legal person who assembles, packages, processes, fully refurbishes and/or labels one or more ready-made products and/or assigns to them their intended purpose as a device with a view to their being placed on the market under his own name.’[46, article 21].

Therefore, the above statements raise some thoughts on the obligations and responsibilities of the technology developers who only provide specific technology services; thoughts particularly relating to their fears of litigation. For example, if the developer only provides their app’s platform to fit the design that was proposed by another stakeholder, the app is launched under the developer’s name as they are the platform provider, would the developer be perceived to be the ‘manufacturer’ and take responsibility for the app under the current legislation? These complexities may explain why technology developers avoid supporting the apps with action plan features that potentially fall into the ‘medical device’ category.
6.4 Strengths and limitations

This was a desktop review of the current app-related legislation informed by my working experience on developing technologies. The discussion provided a general idea of the stakeholders’ involvement in the app’s life cycle. However, the general involvement description did not apply to the app that involves subcontractors; and the discussion only reflects my lay-viewpoint on the issue and did not reflect lawyers’ views.

6.5 Conclusion

Safety is paramount, and regulation is important, to protect asthma app patients, but measures to protect users need to be applied proportionately to the risk. Generating safety data takes time and adds cost to app development; therefore, evidence will always lag behind the technology cycle. Supported self-management is an evidence-based intervention which improves outcomes; an asthma action plan is one of the core elements to support asthma self-management. Future research and legislative works is needed to address how an asthma action plan can be implemented in a viable digital format.
Chapter 7 (Phase 2) Modelling key aspects to develop an app prototype and the feasibility study

Objectives in phase 2
To develop an app prototype and identify the key questions for the feasibility study

In this phase, I used the findings in phase 1 to develop an app prototype and to make decisions about the feasibility study (phase 3). To do this, I convened some lay and professional advisory groups and sought the advice of our technology partner and University sponsor on legislative matters.

7.1 Advisory groups and technological partner

The lay advisory groups were formed by four asthma patients invited from the Patient and Public Involvement group in the Asthma UK for Centre for Applied Research (AUKCAR).

The professional advisory groups were formed by four GPs and two asthma nurses at the Primary Care Respiratory Society (PCRS) conference, also a GP in the AUKCAR.
The technology partner is a technology company who provided the app’s platform and database in this study. The company had experience on configuring their app’s platform on Parkinson’s disease and the management of chronic pain.

What did I ask these advisors to do?

The practical app’s delivery issues were discussed in the lay and professional groups. They advised me on how to explain the study and form questions to patients; how we would like patients to log their data and how to deliver the prototype in practice. The discussions were informed by the findings in my review and analysis in phase 1. In addition, the advisory group members had their practical experience of managing their asthma or providing asthma support to patients. Their advice is reported in the following sections.

Having discussed the practical issues with the advisory group, I then discussed and refined the app, as well as the approach to feasibility testing, with my supervisors, the reviewers at the PhD annual review and our technology partner, uMotif. Positive feedback was obtained from the discussions.

7.2 Developing the app prototype and exploring legislative issues in related to the app prototype

7.2.1 Patients’ perspectives

What I had found in the social discussion forum analysis review?

These were patients who asked questions about their asthma, and shared their own conditions and asthma experiences through online discussion forums. A number of mobile apps’ features to support self-management such as: i) monitoring peak flows, symptoms, and medication use, ii) monitoring indoor or outdoor triggers and pollutants, iii) receiving feedback or advice for further action on their asthma, were all discussed positively by asthma patients who were active in the online social discussion forum (see chapter 4). Asthma action plans were not discussed, though one app known to have an action plan was viewed positively. Different patients valued different features and definitely ‘one size does not fit all’.

What was advised by the lay advisory groups?
The lay participants agreed with the features of logging peak flow on a 3 colour graph, pollen count and action plan. They advised that if patients were to be expected to download the app prototype online by themselves, they would need helpline support for any technical problems such users may encounter.

*What did I decide to include in the app?*

Asthma action plan, monitoring peak flows, symptoms, medication use, monitoring indoor or outdoor triggers and pollutants, receiving feedback or advice for further actions about the users’ asthma, were the features that should be implemented in the app prototype if they could be supplied by our technology partner. Sufficient technical support such as enquiry email and a telephone line should be provided for patients; it could be either operated by our technology partner or me or both.

7.2.2 Clinical perspective

*What I had found in the systematic review?*

Several models of ICT intervention to support asthma self-management were described in the literature (see chapter 3). The models were a) mobile phone app, b) web application, c) SMS, d) electronic inhaler and e) customised asthma monitoring system. No significant correlations had been found between the interventions’ associated features and clinical effectiveness[68]. In general, these interventions required patient participants to regularly input their asthma symptoms and intake of medication. Feedback took the form of an alarm sent to healthcare professionals for a follow-up consultation or automatic machine generated advice, according to patient’s agreed action plan (GINA guidelines)[8]. Medication reminders and a decision support system for healthcare professionals were set up in some of the interventions.

*What did the guidelines and professional advisors suggest?*

The BTS/SIGN guidelines recommend that “all people with asthma (and/or their parents or carers) should be offered self-management education which should include a written personalised asthma action plan and be supported by regular professional review”[24], though not all asthma patients in the UK have an action plan. In addition educating patients about self-management was not a ‘single event’...
but required on-going support as one of the duties of good professional healthcare.

The professional advisory group stated that the action plans they used were paper-based, and that some patients didn’t use their paper plans because they lost them or didn’t always bring them for their consultation. If asking patients to log their asthma symptoms, the Royal College of Physicians’ three questions (RCP3Qs)[173] would be easily understood by patients and was part of the asthma review in the practice. Other logs that they would like to see were: a) the peak flow value, b) numbers of medication doses (preventer, reliever and steroid), c) symptoms of sneezing/ running nose/itchy eyes, d) smoking and exercise intensity. The frequency of data logging could be flexible, either daily or weekly, depending on each patient’s needs. The group further advised that the app should prompt patients to look at the action plan when their symptoms were getting worse. They suggested the thresholds to prompt patients to use their action plan throughout the discussion. Details of the questions and thresholds are presented in Appendix 8.

What did I decide to include in the app?

An action plan should be the core feature of the app prototype. The advice from the action plan could be auto-generated with reference to patient’s symptoms that they have input by themselves. To use the app with an action plan, logging asthma symptom manually and sharing the logs to GPs or nurses during regular consultations, could be a substantial form of learning to self-manage, and should be implemented in the app. RCP3Qs[173], peak flow value, numbers of medication doses (preventer, reliever and steroid), symptoms of sneezing/ running nose/itchy eyes, smoking and exercise intensity should be the questions to be used for logging patient’s symptoms; also the app should allow daily or weekly logging. Features to encourage medication adherence, such as medication reminders, were worth implementing but were subject to, and limited by, the module that our technology partner could provide. Feedback with alarms generated for professional to follow up was encouraging healthcare professionals to monitor their patients, as opposed to encouraging patients to look after themselves and seek help from GPs or nurses when needed, so the feedback alarm option would not feature in the app prototype. Supporting healthcare professionals’ decision making was not the primary aim of
this prototype; therefore, a decision support system for healthcare professionals
would not be implemented in the prototype.

7.2.3 Technology/ marketing perspective

*What had I found in the app’s review?*

Monitoring was the commonest feature found in the currently most downloaded
(100,000 - 500,000) asthma apps in the market. (see section 5.4)

*What digital options are available to support asthma self-management in routine
practice?*

Current practice routines for providing care for asthma patients are well structured
and defined[8, 24]. Asthma patients were asked to meet with their asthma nurse to
review and discuss their asthma on an annual basis; extra consultations can be
requested by patients if their condition is getting worse or becoming unstable. Some
healthcare professionals reminded patients about their regular consultation by letter
or SMS. NHS and Asthma UK provide useful information (for example an inhaler
technique video, seasons-relevant advice and updated information) as well as query
hotlines for patients. A personalised asthma action plan template and instructions are
available to be downloaded from the Asthma UK website[36]. Pollen counts, air
temperature and wind speed, which were the triggers for some patients, are available
on the Met Office website. Self-monitoring features were available on some asthma
apps on the Android or iOS market. Existing apps’ libraries and module were able to
provide basic support for patient monitoring. Clinical tools suggested in the
BTS/SIGN guidelines[24] are available to assess patients’ conditions. These tools
are: i) spirometry, ii) peak expiratory flow(PEF), iii) the Asthma Control
Questionnaires (ACQ), iv) the Asthma Control Test (ACT), v) the Royal College of
Physicians (RCPs’) 3Qs, and vi) the mini Asthma Quality of Life Questionnaire(AQLQ).
Peak flow is easy to monitor and can be measured by a peak
flow meter. Some of the meters can even connect to the app via Bluetooth.
Questionnaires can be implemented on an app without any problems. Other possible
measurable parameters which are not practical are a) airway responsiveness, b)
exhaled nitric oxide (FeNO) and c) eosinophil differential count in induced sputum.
Airway responsiveness is not available as a routine test, as it required hospital
facilities to run it. FeNO needed to be measured by large and expensive equipment
which is not usual in home monitoring at the moment. The eosinophil differential count is not available in home monitoring, as it is measured by research tools or in tertiary care clinics.

*What were the options to share data between my app prototype and the practice?*

**Figure 27 Options for data sharing**

Having explored the system architecture in the introduction (section 1.8.3), there were three options available to share data between our patient participants and practice. These are illustrated in Figure 27. They were technically feasible.

- **Option one** was to create a standalone platform to establish direct data exchange between the app and the NHS services. However, this option needed yearly application and approvals from the NHS, which was a challenge for a three years PhD project.

- **Option two** was to integrate the app with the principal platforms - TPP SystmOne, EMIS Web, InPS Vision and Microtest Evolution. It could be either inserting their application module on the app or to create login links on the app for patients to login to their system. This option was user friendly and enabled data synchronisation between different parties. However, the charge of the official module developed by the principal platforms was
expensive. Our technology partner was not paid to provide custom-made code; instead, they provided configuration on their app platform. If I developed the module by myself, around an extra six months would be needed to develop the code and test its stability before we asked for ethical approval, which was not feasible in terms of the time frame. Therefore, this was not a realistic option.

- Option three was not to create direct data exchange between the NHS services and the principal platforms. This option could be done by sharing the logs with practices by separate emails or shared links. The log could be plotted on graphs over time in PDF format and send to ‘Docman’ or shared with practices via a link. Information about the patients would be entered manually by patients or their medical practice. Our technology partner can provide the shared link settings on the prototype. However, this possibility was not user friendly; the data between the app, the information in practice and NHS may not be synchronised, resulting in the GP receiving an uncontrolled amount of data from patients. Previous studies have suggested GPs wanted the app data to be integrated with the electronic health records (EHR) [174, 175].

What were the app’s features and resources that our technology partner provided?

Our technology partner had been paid to set up an app, store cloud data and technical enquiry support in this project. Instead of providing a bespoke app, they provided application module (features) for us to choose. Configurations on the module could be made for our research purposes. They did ‘native app’ as opposed to ‘web app’ and ‘hybrid app’[57]. Logs by patients were stored in their cloud database when the phone was in online mode. Data logged in offline mode were temporarily stored on the phone memory and sent when the phone was reconnected to the internet. Logs were not available to be sent to the common clinical computer platforms, such as EMIS and VISION. The available module included i) Motif segments (ten questions and logs in a flower format (see section 7.3), ii) task and medication reminders, iii) diary with a feature of taking photos, iv) lung function log (pulse oximetry (%), forced vital capacity (FVC) and forced expiratory volume (FEV1)), v) pop up log reminder, vi) health report on a graph and vii) sharing reporting to healthcare
professionals via a shared link. A trial module was available to allow data sharing from activity tracking gadgets.

What did I decide to include in the app?

The app prototype would be a native app with basic features of: a) ten questions logged in a flower format, b) task and medication reminder, c) diary with a feature of taking photos, d) standard lung function log, e) pop up log reminder, f) asthma action plan, g) health report on graph and h) sending reports to healthcare professionals via a shared link. Connection to a smart inhaler and activity tracking gadget was not fully supported by our technology partner, therefore, these features were not included. The features that I had found in the systematic review and analysis but which were not available on the app prototype, would be asked about in the interview, questions and online questionnaire; therefore, patients would given a chance to express their views about gadgets and other features in both interviews and online questionnaire.

There was no direct data sharing between the app and principal clinical platforms because this was not supported by our technology partner.

An action plan was implemented in the app prototype and the Asthma UK action plan[36] was chosen instead of the Lothian action plan because it was recommended by the guideline[24] and it provided a more comprehensive set of instructions to patients. Those patients who had already got a paper-based action plan could copy the data from the paper to the app; patients who didn’t have an action plan could ask nurses for a paper based action plan or fill in the data directly onto the app. If necessary, this might mean an extra consultation with a nurse to help the patient fill in their action plan on the app.

Links to the available asthma information were implemented in the app. These links provide information such as inhaler technique, asthma information suggested by Asthma UK, the NHS, as well as the Met Office’s pollen counts, temperature, wind speed and other management features. Patients were required to click on the links and features when information was needed. In addition, making logs and reviewing logs in the app was also an iterative self-learning process, which complied with the suggestions in the BTS guidelines[24].
7.2.4 The legislative perspective

Medical device legislation was a barrier during the app prototype development. We (I, my supervisors, our university sponsor, the MHRA, and our technology partner) had different interpretations of the risks that this app prototype would bring to the participants in the study. The asthma action plan, which provided advice to patients, was the feature that raised the most concerns, and iterative discussions were carried out to clarify the problem. The key discussion was about whether our app was a ‘medical device’. The different views, from us and the stakeholders, are listed below:

- **I and my supervisors**: We thought the criterion in question is ‘software intended by its manufacturer to be used specifically for — ‘diagnosis, prevention, monitoring, treatment or alleviation of disease’ (MEDDEV 2.1/6[176]). Our app was certainly not diagnostic or preventative, and the only monitoring was ‘(patient) self-monitoring’, when a patient could log their symptoms, read and share their logs to their medical practice. The action plan might count as ‘treatment or alleviation of disease’, but it was only a template directly transcribed from the Asthma UK action plan, and which had to be completed by the patient’s own GP or asthma nurse. It could give no advice until it had been completed.

- **Our sponsor and the MHRA**: our sponsor was firstly advised that our study was a “clinical investigation or other study of a medical device” in the NHS ethics application. We were not sure if the app should fall into the ‘medical device’ category, as the action plan gave ‘advice’ to patient for adjusting their medication when their symptoms were getting worse. Although the advice on the action plan was given by their healthcare professionals(GP or asthma nurse), there was a possibility that the app give wrong advice to patients. For example, a) according to the flow chart in the MEDDEV 2.1/6[176], the advice on screen might be blurred so that patients could not read it clearly; b) the programme algorithm might have bugs which gave wrong triggering thresholds and gave wrong advice. Therefore, our sponsors sought further advice from the MHRA.

- **Our technology partner**: they showed their worries and reluctance to implement an asthma action plan on the app because if the advice in the action plan was triggered by the patient’s logs, no matter if it was a pop up
advice or just a sentence on the screen, giving advice on app could be interpreted as coming from a ‘medical device’ app.

A consensus was reached after iterative discussion, and the final app prototype was not judged as a ‘medical device’ by the MHRA because the app was a) a template directly transcribed from the freely downloadable Asthma UK action plan b) the action plan was completed by their practices c) the patient was advised in the app that they should make their own decision to manage their asthma and d) the app was targeted to the 16+ adult patients for a research study as opposed to commercialisation. However, the app prototype must not have pop-up advice triggered by the thresholds, meaning that the action plan must not appear on the screen automatically when patient’s symptoms were getting worse. Instead, there was a sentence ‘Please look at your action plan’ on the ten question segment screen, when patients’ logs were at their thresholds. The norm of this feature was to let the patient decide for their self-management actions as opposed to being directed by the app.

Thus, I had refined the action plan on the final prototype with our technology partner to meet the requirements. This discussion substantially prolonged our NHS ethics and research governance application time in the study.

7.3 Description of the final app prototype

The name of the final app prototype is the ‘A4A’, App for Asthma. The app incorporated an asthma action plan with other monitoring features. Users can monitor 10 aspects of their asthma status by completing the segments of the 10 question monitoring ‘motif’ (see Figure 28 with screenshot of the 10 question monitoring ‘motif’). The 10 questions included the standard morbidity questions of the Royal College of Physicians three questions (RCP3Qs)[173], peak flow, use of reliever inhaler, other medication use and lifestyle status. Appendix 9 illustrated the system architecture of our app prototype.

The segments were:
1. In the last week how many nights have you woken because of your asthma?
2. In the last week, on how many days have you had your asthma symptoms?
3. In the last week on how many days has your asthma limited your activities?
4. What is your peak flow?
5. In the last day, how many doses of your reliever (blue) inhaler have you used?
6. Have you used the preventer inhaler today?
7. Have you taken any steroid tablet (mg) this today?
8. Do you have sneezing/running nose/itchy eyes in the past 24 hours?
9. Have you smoked today?
10. Have you done any exercise today?

Figure 28 Screenshot of the 10 question monitoring ‘motif’

The app provided links to useful information sources: a) Asthma UK website, b) Asthma UK updates, c) latest publications about asthma, d) inhaler demo video, e) social forum of Asthma UK, f) weather, pollen count and air quality information. There was an option for completing a daily diary, setting medication and task reminders.

In addition the app included a template for the asthma action plan. This was an electronic form of the Asthma UK paper action plan which is freely available for anyone to download[Figure 1]; the form may be accessed via the electronic health record used in many UK practices. The app version of the Asthma UK action plan is a template involving personalised information about recognising deterioration in the patient’s condition. The actions to be taken have to be completed by the patient’s own clinical advisor (see Figure 29 Screenshot of the plan (everyday care), Figure 30 Screenshot of the plan (worse)).
The Asthma UK Action plan also included advice for dealing with emergency attacks which follows guideline recommendations[36] for dealing with emergency attacks. This option emphasises the means of accessing medical advice as well as how to provide emergency relief whilst awaiting assistance. (see Figure 31 Screenshot of the plan (emergency flow chart)).
I find it difficult to walk or talk.
I find it difficult to breathe.
I’m wheezing a lot or I have a very tight chest or I’m coughing a lot.
My peak flow is below:

THIS IS AN EMERGENCY TAKE ACTION NOW

- Sit up straight – don’t lie down. Try to keep calm
- Take one puff of my reliever inhaler every 30 to 60 seconds up to a maximum of 10 puffs
- A: If I feel worse at any point while I’m using my inhaler
- B: If I don’t feel any better after 10 puffs
- C: If I feel better make an urgent same-day appointment with my GP or asthma nurse to get advice

If I feel better, and have made my urgent same-day appointment:
  • Check if I’ve been given rescue prednisolone tablets
  • If I have these I should take them as prescribed by my doctor or asthma nurse

Figure 31 Screenshot of the plan (emergency flow chart)

To remind participants to go back to our app, a pop up push notification was set at 18.00 everyday by default on our app. This timeslot was suggested by our software partner who, from their experience, was aware that this was the timeslot when most users were less busy. However, participants were given the option to change the preset reminder time of 18.00 or to disable this reminder.

Other features in the app included: a) medication record (a short summary of the medications which was using by the patients), b) medication reminder, c) task reminder, d) lung function (logs of the actual peak flow value), e) diary, f) health report (a summary of the logs and was able to send the report to practices via a shared link), g) app tutorial and h) enquiry box. The screenshots of the features and description of the features were shown in Table 14 and Table 15.
Table 14 Screenshots of the features

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td><img src="image1" alt="Home screenshot" /></td>
<td><img src="image2" alt="Motif screenshot" /></td>
<td><img src="image3" alt="Health report screenshot" /></td>
<td><img src="image4" alt="Asthma action plan screenshot" /></td>
<td><img src="image5" alt="Diary screenshot" /></td>
<td><img src="image6" alt="Medication screenshot" /></td>
</tr>
</tbody>
</table>

7. Medication reminder

8. Lung function

9. Task reminder

10. Enquiry box

11. Tutorial

12. Setting

We hope this Tutorial answers most of your questions on how to use the UMotif app. If you have any other queries, please drop us an email to contact@umotif.com

About UMotif
- Overview of the app
- Enquiry box
- Technical Support

Terms & Conditions
- Privacy Policy
- Version 2.6.1

Accessibility
- Units
- Location Data
- About UMotif

Privacy Policy
- Data and photo notes
- Logout

Settings
- Accessibility
- Units
- Location Data
- About UMotif
- Terms & Conditions
- Privacy Policy

Logout
<table>
<thead>
<tr>
<th>Features</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Home</td>
<td>This allowed quick access to the 10 questions segments, health report and diary. A menu button was provided on the left top corner of the app to allow access to different features.</td>
</tr>
<tr>
<td>2. 10 questions monitoring motif</td>
<td>It contained 10 questions for patients to log their asthma conditions (e.g. symptoms and medications).</td>
</tr>
<tr>
<td>3. Health report</td>
<td>It plotted patient’s logs over time. Patients can share this report with their healthcare professionals via a shared link.</td>
</tr>
<tr>
<td>4. Asthma action plan</td>
<td>This was the template of the Asthma UK action plan. Patients were advised to fill this in with their practices.</td>
</tr>
<tr>
<td>5. Diary</td>
<td>This allowed patients to use free text and pictures to log their activities</td>
</tr>
<tr>
<td>6. Medication</td>
<td>This allowed patients to record their medication in detail (e.g. its name, image and the dosage).</td>
</tr>
<tr>
<td>7. Medication reminder</td>
<td>This allowed patients to set an alarm to remind them of their medication.</td>
</tr>
<tr>
<td>8. Lung function</td>
<td>This allowed patients to make logs of their lung functions, such as their best peak flow in numbers.</td>
</tr>
<tr>
<td>9. Task reminder</td>
<td>This allowed patients to set alarms to remind them to do tasks (e.g. do exercise)</td>
</tr>
<tr>
<td>10. Enquiry box</td>
<td>These enquiries were sent to our technology partner and me to answer. Also, they were used as the qualitative data for further analysis.</td>
</tr>
<tr>
<td>11. Tutorial</td>
<td>Patients were given an interactive tutorial in the registration process. Here, this tutorial provided comprehensive instructions to remind patients how to use the app.</td>
</tr>
<tr>
<td>12. Setting</td>
<td>This allowed patients to enlarge question segments, change the input units, allowed location sharing and provided details of the app’s policy.</td>
</tr>
</tbody>
</table>

Table 15 Description of the features
7.4 Defining the three months feasibility study

7.4.1 Study design

The prime consideration in this feasibility design was to further ask if the smartphone app, or in a broader sense, if technology was a worthwhile option to support asthma self-management from the three perspectives: i) clinical, ii) a patient’s and iii) a technological perspective. The legislative issue was further explored by summarising the advice of our technology partner and University sponsor.

A mixed method research design was chosen for this feasibility study. In research, there are two main designs: qualitative and quantitative; qualitative study is mainly used to understand people. This approach to research is concerned with people’s opinions, experiences and individual feelings. It uses verbal description to detail data[177]. In contrast, quantitative research measures occurrences and outcomes. It uses mathematical formulae to express functional relationships between people or objects. Quantitative study is useful to look into quantifiable physical objects; however, such an approach does not provide a rich insight into human behaviour[178]. Therefore, I decided to use the mixed methods: quantitative data to explore the use of the app and quantify the preferences of app users; and use qualitative data to give me the depth of understanding. I a) interviewed patients and healthcare professionals before and after the use of our app’s prototype, b) sequentially measured patient’s download rate, retention rate, patients’ usage frequency of the app’s features, and c) simultaneously analysed both data at the end of the study.

What are the strengths and weaknesses of using mixed method?

There are a number of advantages to use mixed methods. It provides a richer and more comprehensive dataset for analysis and allows the opportunity for triangulation of results. The weaknesses of one approach can be complemented by another: qualitative findings may validate quantitative results. Also, the findings from one approach may be able to inform other aspects of the study. For example, the comments from qualitative interviews could inform the design of an app and conduct of an intervention to assess the effectiveness. Moreover, the results from one
approach can add insights and understanding that another approach may miss. For example, a quantitative assessment of response rate to social media compared to practice recruitment may focus the qualitative exploration on the differences in triggers, motivation and ability associated with the different recruitment strategies.

However, there are also challenges in using mixed methods. Mixed methods require researchers to be trained in both qualitative and quantitative approaches. It can be challenging to choose appropriate approaches to make up an overall study design. Also, it may be more difficult to manage both data collections simultaneously and, more time and resources may be required [179, 180, 181].

**Best practice for mixed methods studies**

The National Institutes of Health (NIH)[182] provides advice on best practice for mixed methods research in health sciences. Creswell et al [183] recommend a clear plan from data collection to analysis and emphasise the importance of combining the qualitative and quantitative approaches to increase the rigour of the study. They also describe the importance of checking that using mixed methods is likely to contribute to a better understanding of the research problem than using either one of the approaches.

Creswell suggests there are many typical reasons to use mixed methods such as to enrich the meanings of a single perspective, to contextualise information and provide a more comprehensive understanding of a problem [183]. In my study, I choose mixed methods because I wanted to develop a more comprehensive understanding of how patients would adopt and use of an app to support their self-management was. For example, if download rate from different recruitment strategies suggested social media was an effective way to attract patients to download the ‘app’; I would be able to use the patients’ interviews to explore practical reasons why patients decided to download the app, and the questionnaires would enable prevalence of these opinions to be quantified. The retention rate would indicate the number of patients who stopped using the app over time, but will not explain why they gave up using the app; the interviews with patients will allow me to explore the reasons behind these quantitative observations.
In my study design, the quantitative and qualitative investigations will be concurrent within a single study: the app’s usage rate will be measured while the interviews are being conducted. This is to maximise the amount of data collected within a comparatively short study period – an important consideration in the evaluation of technology in which development is determined by commercial timescales.

I will not prioritise either the qualitative or quantitative approaches; they will be equally emphasised, and used to supplement and validate each other. The ‘point of interface’ or ‘mixing of data’ will occur iteratively throughout data collection as, for example, the responses to the baseline questionnaire are explored in interviews, and interview findings will be used to inform the final questionnaire. Data (patients’ downloads/usage, questionnaire responses, qualitative themes) will be synthesised at the analysis stage, and both quantitative and qualitative data used to answer the research objectives as appropriate.

O’Cathain’s checklist for good reporting of a mixed methods study guideline (GRAMMS)[184] identifies best practice and includes items such as reporting the justification for using mixed methods, providing clear descriptions about the study design, method, integration and the insights from using the mixed method. I adopted this guideline to report my study and the detail is reported in the checklist (Appendix 10).

What are the challenges of conducting a mixed methods study?

Firstly, combining qualitative and quantitative approaches to make up a study can be time consuming and require researchers to have two sets of skills. Managing both types of research simultaneously or sequentially could be a challenge if the project is limited to a specific timeframe or budget[185]. Secondly, from methodological perspective, qualitative and quantitative are inherently from different paradigms, they represent different ways of viewing the world and how we knew about knowledge. Therefore, combining these two approaches may theoretically cause problems [186]. Thirdly, some researchers have suggested it is difficult to report the results of mixed methods in journals. Many medical sciences journals have restrictive word limits and a ‘distinct methodological base’ which reduces the acceptability of a complex mixed methods study [179].
Feasibility study as opposed to a pilot trial

A feasibility study aims to estimate the important parameters that are needed to design the future study; it does not evaluate the outcome of interest[187]. Also, a feasibility study will not randomise participants; it is usually a observational study to test the acceptability of an intervention and the utility of outcomes. Several versions of interventions may be tested. In contrast, a pilot trial aims to conducted a smaller experiment to prepare for future interventions by testing the clinical and process effectiveness in this case of the smartphone app which has been designed to support asthma self-management[188]. The pilot study will test randomisation procedures and recruitment of different arms of a trial and possibly retention. In addition, it may establish variation in the outcomes under consideration so that a power calculation can be made for a future trial[187].

I was interested in assessing the feasibility of my app prototype and recruitment strategies, as opposed to running a miniature version of a trial. Therefore I decided to use the feasibility study option, whose parameters will be used to inform my further studies, after my PhD research is completed.

Interviews

Different qualitative strategies were considered before deciding on the data collection and data analysis for the qualitative study. Individual interviews were used to explore patients’ and practices’ views in this study.

An interview is a form of verbal conversation to elicit participants’ thoughts[189]. There are three types of individual interviews: i) structured, ii) semi structured and iii) unstructured. A focus group is another option to capture participants’ thoughts.

A structured interview: follows a standard set of questions and with the conversation always being conducted in the same order and the same way[189].

A semi-structured interview: is half-way between a structured and unstructured interview. It follows a topic guide to keep conversations in line with the research aim. It uses open-ended questions to provoke conversation[190]. A topic guide may evolve iteratively as themes emerge during the interviews with participants. A semi-
structured interview could take place with an individual or in a group and usually lasts between 30 minutes to an hour, and occasionally a little longer[191].

**An unstructured interview:** is the opposite of structured interview. It is in essence an informal conversation based on unplanned questions[189].

**Focus group:** involves a group of people partaking in a discussion, that would usually last for 90 mins[192]. Interaction between participants should generate various opinions; however, these views will be limited if confined to a discussion on the topic that the researcher wants to be discussed[190]. The advantage of a focus group is to allow participants to bounce ideas and potentially come up with ideas which had not been considered by the researcher. However, they are difficult to organise and some people feel insecure in groups and have difficulty speaking in them.

In my study, I chose the semi-structured, individual interview model because I wanted to obtain individual opinions, to explore those opinions in depth, and prevent other people influencing the interviewee’s thoughts. Also, I anticipated participants might tell me about their personal experiences or attitudes to other digital products.

**The qualitative approach**

In the previous literature, the person-based approach suggested by Lucy Yardley[193] was the approach that reflected my focus on exploring users’ views to assist the development of a telehealth intervention. A ‘think-aloud’ interview, with an iteratively refining process, was advised in her approach. She asked patients to speak out their views after using the app prototype, which gave a rapid and effective approach to capture what users want in order to refine a final prototype. However, during my pilot interviews with volunteers from the lay advisory group, I found that this approach was indeed leading the participants to focus on refining the app prototype for the research, which in this study was not my prime aim. My aim was gain a wider understanding of what features users would like to see in the app. I also found that

- starting the discussion with patient participants, explaining the use of this app prototype and stimulating discussion as opposed to testing the prototype’s effectiveness, encouraged various feedback (positive, neutral and adverse)
• asking patients to explain their asthma condition, experience and how to look after their asthma, followed by asking what they want to ‘see’ in an app to support their self-management, would help them to think of what they need from the app prototype

• in the context of a questionnaire, asking patients if they agree or disagree on the features would work better than asking them to rank the features, because some features they thought maybe equally important.

Therefore, I adopted these findings to design the qualitative interviews and inform the questionnaire for the participant patients.

*Quantitative data*

In reality, not all patients have expertise in technology; therefore they may not be able to tell or know exactly what they want in an app; also they may not know how an app can help them to manage their asthma until they have a ‘hands-on’ experience with using an app. Therefore, a) their download rate, b) usage frequency on different app’s features and c) the retention rate were useful parameters to explore how they liked, or did not like, the app and how they got on with the app. I also designed a questionnaire to capture their opinions by rating ‘agree’, neutral’ and ‘disagree’ on the features identified in the systematic review, online social analysis and app review. Therefore, the collected opinions were not limited to the features that the patients knew.

*Theoretical underpinning*

I adopted i) motivation, ii) trigger and iii) ability as the basic elements in the topic guide because motivation, trigger and ability are the key elements in recent psychological initiatives, such as a) the COM-B model (behaviour change wheel)[ 194 ], b) Fogg behaviour model[ 195 ], and c) PRIME theory of motivation[196]. Compared with the COM-B model and PRIME, Fogg’s behaviour model is focused on the persuasive technology which matches the purpose of my app prototype (see Table 16). Therefore, I adopted Fogg’s motivation, trigger and ability as the directions to explore patients’ responses in the topic guide to aid the interviewing of patients.
Table 16 Comparison between Fogg behaviour model, COM-B and PRIME

<table>
<thead>
<tr>
<th>Model</th>
<th>Descriptions</th>
<th>Core element(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fogg behaviour model[195]</td>
<td>It is a model of persuasive technology. It aims to help identify those features that the technology needs to change users’ behaviours from how people generally perform.</td>
<td>Motivation, trigger, ability (easy to do)</td>
</tr>
<tr>
<td>COM-B[194]</td>
<td>It is a synthesis model, developed from 19 behaviour change frameworks identified in systematic reviews on a wide range of disciplines and approaches. It aims to help with designing and evaluating behaviour change interventions and policies.</td>
<td>Motivation, opportunity, capability</td>
</tr>
<tr>
<td>PRIME[196]</td>
<td>It is a model for motivation, suggesting motivation as ‘Processes in the brain that energise and direct behaviour’. It aims to help with explaining, predicting and influencing behaviour.</td>
<td>External stimuli, internal environment results in a sequence of plans, evaluations, motivation, and impulse which lead to responses.</td>
</tr>
</tbody>
</table>

- **Fogg behaviour model**: Fogg suggests that “motivation, ability and a trigger must converge at the same time for behaviour to occur”. When these three elements are presented, action will occur: i.e. when the trigger successfully prompts the user to think about the action, his/her motivation is high and it is an easy task for him/her. Fogg suggested 15 ways to change behaviour, in a format referred to as the ‘Fogg behaviour grid’[197]. *Adoption* (to download the app prototype) and *adherence* (continuous use of the app to manage asthma) were the two main behaviours that my app prototype wanted patients to perform. *Download* is a one-off behaviour, therefore adoption is either a green dot or blue dot behaviour. A patient who is familiar with downloading an app is described as exhibiting ‘green dot behaviour’ whereas a patient who is less familiar with downloading, is said to show ‘blue dot behaviour’. Continuous use of my app to look after asthma is a new behaviour that I wanted patients to start and maintain; therefore, it is the green path behaviour that I am interested in and wish to promote.

- **Motivation**: motivation and ability can be traded off in Fogg behaviour model[195]. If a participant’s motivation is high, they can perform a task which is hard for them. In this study, the motivation was anticipated to be helping the research and to have improved asthma control.

- **Trigger**: It is described as ‘stimuli’ in the PRIME theory of motivation[196]) and was needed to prompt users to think of taking action. In this study,
‘action’ referred to prompting patients to think of adopting an app to support their asthma self-management or to go back to the app when they needed to. In another words the individual would have a sense that an app was something to help in their asthma self-management journey. For ‘adoption’, the trigger was the ways to prompt patients to think of downloading the prototype. Invitation by practice letter, invitation by asthma nurse and invitation on social media were the three initiatives chosen, because they were the feasible ways to reach patients. For ‘adherence’, the trigger was the pop up notification to use the app prototype, which was set for 18.00 every day.

- **Ability**: refers to the user’s ability to carry out or implement the target behaviour. Fogg called it ‘simplicity’. It is similar to the ‘self-efficacy’ found in some models and ‘capability’ in the COM-B model[194]; however, ‘simplicity’ is less focused on the confidence the users must have to perform the target behaviour. In this study, the user’s ability was referring to the simpler concept by Fogg: how simple was the app for patients to download and use? In response the app prototype was designed to be easy to download and use.

### 7.4.2 Selecting participants

**Purposively sample participants for the qualitative study**

Having decided on the research approach, I next considered the patient participants that I would like to recruit in this feasibility study. My choice of inclusion criteria, exclusion criteria and purposive sampling criteria are shown in Table 17. Purposive sampling is a technique used in qualitative research to identify and select a broad range of information-rich participants[198]. Such sampling is intended to maximise efficiency within limited resources[199]. I was interested in adult asthma patients who can take care of their own asthma. This focus was because the dynamics of app use are likely to be different if it is the parent(s) or other carers who are taking responsibility for the patient. In addition, the format of effective self-management in pre-school children is unclear. I also excluded people with very severe asthma, because they were likely to need very specific emergency plans (e.g. direct access to hospital, or ‘panic buttons’ to 999) or to require specific monitoring and self-
management according to their condition. Such severe asthma patients should have a personalised action plan from their specialist clinic. Finally, patients’ preferences on the attractive and adherence features may be influenced by their experience of an action plan and healthcare app. I therefore aimed to purposively sample patients from different age groups, gender (male/female), with and without experience of self-management with an action plan, and with/without experience on healthcare app. These constructs were important because the dynamics of app adoption and usage are likely to be different in different generations, genders, self-management experiences and healthcare app experiences. I therefore chose them to be sampling constructs.

Table 17 Inclusion criteria, exclusion criteria and purposive sample criteria

<table>
<thead>
<tr>
<th>Inclusion criteria</th>
<th>Adults (≥ 16yrs) on the ‘active’ asthma register of their medical practices. ‘Active’ asthma is defined as having a coded diagnosis of asthma and having been prescribed an asthma medication in the previous 6 months.</th>
</tr>
</thead>
</table>
| Exclusion criteria | • People with very severe asthma, e.g. under a hospital clinic, or who have had an admission within the previous 3 months (who may be expected to have been provided with a paper based action plan by the hospital clinic or prior to discharge tailored to their specific clinical needs)  
• People unable to provide informed consent (e.g. dementia, learning disabilities)  
• People unable to self-manage their own asthma (e.g. in nursing/residential care, cognitive impairment)  
• At the GP’s discretion for other severe or more significant conditions (including other lung conditions such as chronic obstructive pulmonary disease, and people on the palliative care register) |
| Purposively sample | • Age: a range of ages including young adults (16-25) adults (26-60) and older adults (61+)  
• Action plan: with/without an action plan  
• Technology: is/is not a frequent healthcare app user |
Recruiting participants for the quantitative study

In addition to the above criteria, I would like to understand the adoption and retention rates of patients who received their invitation in different ways: a) by a letter from the practice, b) by asthma nurse in routine consultation, and c) via Facebook and Twitter from Asthma UK or the Asthma UK Centre for Applied Research. Traditionally, researchers used to ask practices to post invitations to potential patient participants. However, in this IT era, Facebook and Twitter are popular strategies for recruiting people for casual events and using social media would seem appropriate for a digital option such as an app. Therefore, I decided to set up three streams (A, B and C):

A: recruited by practice’s invitation letter
B: recruited by asthma nurse during consultation
C: recruited by Asthma UK Facebook, Twitter and AUKCAR twitter

To provide a naturalised environment which was close to reality, I didn’t provide training to patients to download and use the app. All instructions and training were presented on the patient information sheet and in-app tutorial. Patients were instructed to use a specific activation code to activate the app; this was to help me to identify how the patients were invited to take part in this research.

7.4.3 Deciding on the approach to data analysis

Qualitative studies involve large amounts of data such as words, sentence, narratives and stories. Therefore, analysis is used to fragment and reduce those data to make sense of the material[200]. Examples of analyses include content analysis, grounded theory, thematic analysis and framework analysis.

Content analysis is used to count the number of times that a word or a concept occurs in the data. However, the number of times that the participants mention the application features is not useful to understanding if they would like the features to be included in an asthma app, therefore, content analysis was not suitable.

Grounded theory is a purely inductive and iterative process to develop theory until it reaches the saturated point, where no new information is yielded[104]. However, this study was not aiming to develop theory, therefore, grounded theory was not suitable.
Thematic analysis is used to gain a deeper understanding of the data by identifying themes in the data[200]. This can be used in conjunction with other analytical approaches.

Framework analysis uses a matrix to summarise data. The rows of the matrix are the cases (e.g. the individual participants), the columns are the codes, the cell is the summary. Thematic analysis can be used for data within the columns; case analysis can be performed with data in each of the rows. Also the approach provides a structured way for researchers to reduce data and analyse data across the matrix[201]. There are five stages in framework analysis which are: i) familiarisation, ii) identifying a thematic framework, iii) indexing, charting, iv) mapping and v) interpreting[202,203].

- **Familiarisation**: in this first stage, individual researchers need to familiarise themselves with the interviews, mark down their reflections if any, discuss and re-listen to the recording and re-read the transcripts. At this stage, researchers become aware of the key ideas and recurrent themes of the interviews.

- **Identifying a thematic framework**: researchers read the first few transcripts line by line and make labels (codes) in order to classify the emerging themes. It is important for the researchers to keep an open mind to the new themes, though they may have already anticipated certain *a priori* themes before the analysis. Iterative discussions with other reviewers may be needed to refine the framework.

- **Indexing**: researchers apply the framework to the rest of the transcripts. NVivo is one software designed to help with this task.

- **Charting**: the data are charted into a matrix for further discussion.

- **Mapping and interpreting**: researchers meet together to interpret any interesting ideas, concepts or associations in the data set.

Thematic analysis using a framework approach was chosen to answer the study’s specific questions relating to usability. The approach would also explore the triggers and motivation influencing patients to adopt and/or keep using an app to support their asthma self-management, as well as to explore the features that participants wanted to see. Analysis was iterative, so that insights from the early cycles informed
both the refinement of the app and also the topic guide for later interviews. Enquiries received by our technology partner, my mailbox and our discussion forum were also coded using NVivo.

The main reason to use framework analysis was that it provides clear steps and procedures to summarise data in a matrix, which facilitated the discussion in our multi-disciplinary team. In addition, the matrix was a flexible tool which allowed in-depth thematic analysis of codes such as trigger, motivation, ability and features. However, there were also some limitations to using a framework analysis. It is not suited to heterogeneous data[104], though my findings from the systematic review, online social discussion forum analysis and app review suggested that opinions on the app’s features were unlikely to demonstrate substantial heterogeneity.

Reflexivity

“Reflexivity” is defined as “thoughtful, conscious self-awareness.” My identity as a researcher, and experience in engineering, may influence my understanding of the collected data. I therefore discussed coding with colleagues from different backgrounds and with different experiences. I also presented my data at meetings and conferences so that I could speak with a broad range of professionals including GPs, asthma nurses, researchers, CEOs of technology companies and members in a digital health public relationship company. This range of contacts enabled me to maintain a balance between different understandings and points of view.

Sample size

I decided to interview 15 patient participants as the minimum acceptable numbers suggested for qualitative interviews[204]. Although my study was not aiming to develop any theory, informed by grounded theory where data saturation is crucial, I looked up the appropriate sample size to fit the study’s purpose and timeframe for data saturation. In general, I found that there is no absolute figure for sample sizes in qualitative studies[205,206]. The data are saturated if there were “no new data, no new themes, no new coding, and ability to replicate the study[207]”. Estimations for suitable sample sizes range from 15-60[204,208,209,210]. Fusch suggested there was a direct link between data triangulation and saturation. Increasing data
triangulation was the method to reach data saturation[205]. However, triangulation could result in contradictory and inconsistent results[211].

7.4.4 Choice of outcome measures for the quantitative study and sample size calculation

The benchmarks of app adoption and adherence are usually the download rate and retention rate at 30th, 60th and 90th days. There are other benchmarks that look into the user’s interaction with the app, such as session length and session interval.

The download rate is the number of downloads per month, and was used to determine the adoption rate of our app prototype.

The retention rate was the percent of users who returned to an app at least once at 30th, 60th and 90th days after the app was downloaded[212, 213]. The average retention rate of a general app is approximately 50% at 30 days[212,213]. This general retention rate was used to form the basis of sample size calculations for this feasibility study. Based on a 50% retention rate of the app at the 30th days, a sample of 97 patients will give us 80% power with 95% confidence interval to detect a difference with a maximum half-width of 10% (i.e. 40-60%). This base offers an acceptable precision and is feasible within the recruitment timescale of three months. This was used to determine the adherence rate of our app prototype.

The session length was the duration of each use of the app[214] and session interval is the frequency with which users open the app[215]. These measurements would be useful to determine the adherence patterns of individual features in our app’s prototype. However, they were not available from our technology partner. I therefore calculated the number of people who used individual features at 30th, 60th and 90th days.

7.5 Potential risks and burden of the three months feasibility study

I considered the potential risks and possible burden that the feasibility study may bring to participants, though this study was low risk and unlikely to lead to any intrusive issues for participants or involve vulnerable people. The potential risks and burden that I thought of were:
• There was a potential risk that the patients may presume there was a clinician
to monitor their health data, which is not the case for this app. Therefore, I
had clearly written down in the information sheet what the app did not do. I
also added an item in the consent form to make sure that the participants
understood there was no clinician monitoring their asthma readings, and
therefore they were responsible for accessing advice if their asthma began
deteriorating.

• Patients were asked to complete two short questionnaires at the beginning
and end of using the app. To reduce the associated burden, I constructed on­
line questionnaires with pick-lists plus optional space for free-text comments.

• Stream A (patient recruited by practice’s invitation letter): patients in Stream
A were asked to provide two interviews at the beginning and end of the one­
month trial of using the app. To reduce the associated burden, I conducted
the interview at an accessible venue for our participants. If travel was needed,
my project funding paid the participants’ travel expenses. Professional time
was reimbursed at the rates recommended by Clinical Research Networks
and telephone interviews were offered. People were expected to have and
maintain their own smartphone device and provide their own data
connectivity.

• The quantity of data used by the app was very small and was unlikely to have
a significant effect on participants’ data plans. This was clearly
communicated to participants prior to registration.

• Data security: The data captured on the patient’s mobile phone or home
computer and software was independent of the operating system. The data
were kept securely on the uMotif cloud servers.

• Participants’ data such as their logged health data and app’s usage pattern
were automatically sent from their smartphone / tablet device via secure SSL
encryption to the EU-based uMotif cloud servers, when their device had
internet connectivity (3G / 4G / Wifi). All data sent to the servers is backed­
up in real-time and the database was encrypted for security.

• Participant study data on the servers was only accessible by approved study
staff and partners. Participants were able to see their own data only – not
data from other participants.
• All data were held in accordance with the UK Data Protection Act (uMotif Limited is a notified Data Controller and Processor) and the Health and Social Care Information Centre’s (HSCIC) Information Governance toolkit (uMotif Limited is certified to Level 2 of the Information Governance (IG) Toolkit).

• Each participant agreed to the uMotif standard Terms and Conditions (https://www.umotif.com/termsAndConditions) and Privacy Policy (https://umotif.com/privacyPolicy). These stated that participants own their own data and can request a copy of it at any time.
Chapter 8 (Phase 3) Three months feasibility study – method

In the previous chapter I explained why I chose to undertake a feasibility study and explained some of the key decisions about the mixed method design. In this chapter, I will discuss the methodology of the feasibility study. The result(s) of the study will be discussed in the next chapter. Figure 32 provides an overview of this study.

Objectives in phase 3

1. Feasibility from a clinical perspective: a) to test the feasibility of the using the self-management support features in the prototype app, and b) to identify supporting features that patient and professionals would like added/excluded mapped to the PRISMS taxonomy

2. Feasibility from a patient’s perspective: to test the feasibility of the prototype app, and specifically a) to compare the attractiveness of the app prototype to patients recruited via their practice or social media, and b) to explore the adoptive and adherent features that influence patient engagement with asthma self-management

3. Technological feasibility: to explore the practical barriers to use and to pilot an app in clinical practices

4. Legislative feasibility: to further explore the legislative barriers to develop asthma self-management app to support asthma self-management
8.1 Method

8.1.1 Ethical approval

This feasibility study commenced on 6th June 2016 and ended on 24th July 2017, with the approval of the NHS South East Scotland REC 02 and NHS HRA (this was a cross boundary study between Scotland Lothian and Oxford). The REC reference number was 16/SS/0101 (The approval letters are presented in Appendix 11). All participants gave their fully informed consent to their involvement in this study.

8.1.2 Setting

The feasibility study was undertaken in five UK primary care general practices with at least one asthma nurse to provide asthma care.

8.1.3 Study design

This was a mixed method observational feasibility study with three parallel streams of work.

- (Objective 1) Its aim was to identify the supporting features that the patient and healthcare professionals wanted to see on an app to support self-management. The setting is illustrated in Figure 32. The reason for the three streams was to compare the attractiveness of the app prototype to patients recruited by a mailed invitation to participate in research (stream A); via their practice nurse in an asthma review (stream B) or social media (stream C).
- (Objective 2a) Interviews and questionnaires were used to identify the adoptive and adherent features that influence patient engagement with asthma self-management;
- (Objective 2b) Healthcare professionals from the five participating practices were interviewed for their views on the practicalities of using the app;
- (Objective 3) and to explore any impact this has had on consultations and delivery of self-management support;
- Objective 4 was addressed by logging the process of obtaining regulatory approvals.
Stream A: In a sequential, iterative process, three cohorts of approximately five people with asthma used the app for one month and attended interviews before (to explore initial usability and explore ‘attractive’ features) and after the 1-month trial (to explore practical experience and ‘adherent’ features).

Stream B: Patients were introduced to the app by being given an information pack from the asthma nurse during a routine review and were then invited to download and use the app for three months. The app encouraged them to see the asthma nurse for completion of the personalised asthma action plan. During those three months, they could send enquiries and instant comments to uMotif technical support or our forum. They were asked to fill in short questionnaires before and after using the app.

Stream C: This group of participants were people living in the UK, who came across our app’s information in the market (e.g. on our research website, via friends from our participants in streams A&B, in the Google play store, in the Apple app store or at conferences). They were able to download and register to use our app for three months. During those three months, they could send enquiries and instant comments to uMotif technical support or our forum. With consent, we tracked their usage data and requested completion of questionnaires before and after using the app.

8.1.4 Practice recruitment

I recruited five general practices from diverse demographic areas (e.g. high/low areas of deprivation; predominantly younger/older populations; routinely providing asthma self-management (or not)) to participate in streams A and B. Eligible practices had an asthma-trained nurse willing to participate in the research.

8.1.5 Nurse training

I provided a recruitment pack (see Appendix 12) to the nurse and provided training on recruiting patients. The recruitment packs included i) a 3-minute guide for recruitment (the steps and exemplar scripts for inviting patients to participate), ii) the enquiry emails and study telephone numbers, iii) a log sheet to record the gender and age of the patients who had been given the information packs and iv) an AUKCAR pen. I showed and explained the app prototype to the asthma nurses but they were not formally trained to use the app or to teach patients to use our app. This was because the time for usual consultations was limited and already tight so it was
unlikely and impractical to provide tutorials to patients in a 10-20 minute consultation. It would be easier for nurses to redirect all their enquiries to our technical partner, or me, as we had the technology background and knew the study well. In addition, this was the way that it would be done in a real clinical setting: a minute to invite the patient to use an app to support their self-management was likely to be an acceptable timeframe. The nurses’ feedback in their interviews would let me know if this assumption was correct.

8.1.6 Patient recruitment

Eligibility

Inclusion criteria:

- Adults (≥ 16yrs) on the ‘active’ asthma register of their practices. ‘Active’ asthma was defined as having a coded diagnosis of asthma and having been prescribed an asthma medication in the previous 12 months. From the quality and outcomes framework (QOF), patients are considered as 'currently treated' if they have had a prescription for the medicine within the previous 12 months in the database’s register[216].

Exclusion criteria:

- People with very severe asthma, e.g. under a hospital clinic, or who had had an admission within the previous 3 months (they were expected to have been provided with an action plan by the hospital clinic or prior to discharge tailored to their specific clinical needs)
- People unable to provide informed consent (e.g. dementia, learning disabilities)
- People unable to self-manage their own asthma (e.g. in nursing/residential care, cognitive impairment)
- At the GP’s discretion for other severe or more significant conditions (including other lung conditions such as chronic obstructive pulmonary disease, and people on the palliative care register)
**Patient recruitment (Stream A)**

Practices searched their electronic health record (EHR) and identified people on the asthma register who met the above eligibility criteria. Each practice wrote and enclosed an information pack (see Appendix 13) to a random sample of 100 eligible patients. People who were interested in the study, completed and returned an expression of interest form to me (Appendix 13). The form included some basic demographic details and information about their experience of asthma self-management and their use, or not, of healthcare apps. Respondents confirmed that they had a compatible smartphone/tablet with at least Android 4.3.3 or iOS 7.0 and were able to use an app written in English. On the basis of this information I purposively sampled up to 15 people, based on:

- Age: a range of ages including young adults (16-25) adults (26-60) and older adults (61+)
- Action plan: with/without an action plan
- Technology: is/is not a frequent healthcare app user

Any patients who expressed interest, but was not selected for the qualitative research (stream A), was invited to try our app for 3 months (as part of stream B)

**Patient recruitment (Stream B):** The asthma nurse from participating practices was asked to give information packs (Appendix 13) about the app and the research to all potentially eligible patients seen over the 3-month recruitment phase.

**Patient recruitment (Stream C):** The app was available on Google Play and the Apple app store and information was also available on the research website (http://www.aukcar.ac.uk/a4aappforasthma/), on Asthma UK Facebook & Twitter, on Asthma UK Centre for Applied Research Twitter, and via presentations (see Appendix 13) at UK conferences (PCRS-UK) and the Annual Scientific Meeting of the Asthma UK Centre for Applied Research. Patients wishing to participate downloaded our app from the app store.

8.1.7 Professional recruitment

I invited the GP, asthma nurse and administration staff from the participating practices to participate in interviews (face-to-face or by telephone according to the
interviewee’s preference) before and towards the end of the study. People who were interested in the study, completed and returned an expression of interest form (see Appendix 13) In most practices the key professionals providing routine care for people with asthma (including asthma self-management) were asthma-trained nurses, but I extended interviews to any healthcare professionals who had a role in providing asthma care.

8.1.8 Online consent for reviewing patients’ usage on app

![Screenshots of the online consent](image)

Figure 33 Screenshots of the online consent (left: landing page; middle: information sheet page; right: consent page)

All patients went through the same online process to give consent for providing their app’s usage data for the research. Patients used their smartphone/tablet to download the uMotif app from the app stores. They were prompted to enter the stream code to activate the app. The stream code was a code to identify which stream they were in:

- For stream A participants, they received the code in our confirmation email;
- For stream B, it was clearly printed on the last page of the patient information sheet;
- For stream C, it was clearly shown online (project webpage, online patient information sheet and social forum).

Patients then passed through an eligibility check (see section 8.1.6, ‘eligibility’), read and checked an information sheet before giving consent. After this, they registered an account on the app and were invited to complete their background information and initial questionnaires. Lastly, a short tutorial ‘popped up’ and they started to use the app. Details of this process are presented in Appendix 14.
8.1.9 Consent to interviews

Only stream A patients were invited to provide an interview. Written informed consent for the interviews was obtained prior to commencing the initial interview and confirmed verbally prior to the follow-up interview (after the 1-month trial of using the app prototype). The patient consent form is in (Appendix 13).

8.1.10 Qualitative data collection and analysis

*Patient topic guide*

I adopted the three basic elements (motivation, trigger and ability) of the Fogg behaviour change model[195] and consulted the lay advisors to design the topic guide questions.

*How did these three elements map on to the questions of the topic guide?*

The three elements were the three core directions of the topic guide. Table 18 provides an overview of how the leading questions in the initial interview and follow up interview mapped to three elements as well as explaining what I wanted to know from the questions.
Table 18 Leading questions related to the core elements in behaviour change model

<table>
<thead>
<tr>
<th>Initial interview</th>
<th>Follow up interview and prompts</th>
<th>What did I want to know?</th>
<th>Related elements in the behaviour change model</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Why did you decide to download the app (or not) before the meeting?</td>
<td>• Are you still using the app?</td>
<td>To identify the attractive and adherence elements (e.g. service deployment features/app features/patient’s needs etc) that motivate patient to download or get back to app to support their asthma self-management.</td>
<td>Motivation</td>
</tr>
<tr>
<td>• What made you decide to try out the app?</td>
<td>• What made you keep using it/stop using it?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• What would make you keep using the app in the coming month?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

What triggered your interest in the app?

- Do you use the app regularly – how do you remember?
- What reminders do you use (or not)?

What was the download process? Were there any technical problems?

- Are there any technical problems that you experienced with the app?
- Were there any difficulties communicating with your asthma nurse about the app

To identify the app’s features that was difficult to patients, or difficulties with the interface with the practice

User’s ability

What did the lay advisory group advise?

They were positive about the flow of the questions. I piloted the questions with the lay advisors; the wording that I used in the questions was easily understood by them and precise enough to encourage them to talk on the motivation, triggers and difficulties with using the app. Another observation was that people were more active in discussing their thoughts when having an app in their hand while answering the questions; therefore, I decided to use those questions as the leading questions in my topic guide. At the same time, I prepared a spare mobile and ensured that free internet data connection was available in the interview to enable patients to open the app during their interview. Below is an outline of the topic guide.

Initial interview (before 1-month trial): the interview was in two parts and lasted approximately one hour:

- Part 1: Explore initial usability: I asked the patient about their practical experience of downloading and using the app for the first time (if they
had downloaded) or assisted them to do so if they required support. I then explored whether they had worked out how to use the app (e.g. to perform the usual monitoring tasks, look up information, check their action plan) and gained their initial impression of usability.

- **Part 2: Explore attractive features:** I asked about the features that attracted them to try out the app to support their self-management. Finally, I asked about any features that would encourage them to keep using the app for their self-management.

**One-month trial**

The participant then used the app for one month by themselves. The app encouraged them to see their asthma nurse to arrange completion of the personalised asthma action plan. They could send enquiries and instant comments to uMotif technical support or to our forum. I had access to this open feedback to inform the follow-up interview.

**Follow-up interview (after 1-month trial): the interview was in two parts and lasted approximately one hour**

- **Part 1:** I asked for their usage feedback, specifically for information about any practical problems with navigating the software, recording monitoring data, or accessing their action plan. Respondents were asked whether they had discussed the action plan with their asthma nurse and for feedback on how that had worked.
- **Part 2:** I explored the reason why they kept using, or did not keep using, the app after a month. Were there any adherent features that motivated them to keep using it, or discouraged them from using it? Did they have any suggestions for additional attractive or adherent features?

**Arrangements for interviews and informed consent for healthcare professionals**

I planned two interviews (at the beginning and towards the end of the study) with key professionals (typically the practice nurses) and one interview (towards end of the study) with any other members of the practice team involved in asthma care and/or provision of asthma self-management. I arranged interviews at convenient times and offered face-to-face or telephone interviews according to preference.
Participants were asked for informed consent prior to the interview (arranged by post if the interview was by telephone).

Overview of topics for discussion in the interviews for healthcare professionals

I adopted the basic elements (trigger, motivation and ability) of the Fogg behaviour change model[195] to design the topic guide questions, together with the advice of the professional advisory group to help me refine the questions. An outline of the interview is given below (details are in Appendix 15).

- Initial interview (as patient recruitment started). The first interview focused on the process of inputting personalised data into the action plan for the patient. Also explored were the initial perceptions of the system and the perceived impact of using the app in the consultation.

- Follow-up interview (towards the end of the practice involvement with the project). I asked for feedback on the practicalities of using the app, and asked interviewees to list three good and three bad things about using an app. Any impact our app had had on consultations and delivery of self-management support was then explored. I also asked about perceptions of attractive and adherent features.

Comments from enquiry emails and our online discussion forum

Patients and practices were invited to email or call us (technology partner or me) for technical or study enquires. The enquiry email and telephone numbers were provided on the information sheets. In addition, there was an enquiry message box on the app which was directed to the enquiry email of our technology partner. A discussion forum was set up to allow users to discuss our app prototype. The forum link was introduced on the screen before the user started to use our app prototype.

Data synthesis and data analysis

The interviews were digitally-recorded, transcribed and entered into NVivo for analysis. Notes from my observation of how the app was used (initial interviews) were coded using NVivo. Contemporaneous comprehensive field notes aided contextualisation. Comments from enquiry emails and our online discussion forum were also imported into the NVivo for analysis.
The Framework approach was used in the data analysis (see section 7.4.3 for an explanation for why I chose this approach).

- Familiarisation with the interview: I and my main supervisor (HP) discussed the interviews in meetings; we then compared our thoughts and impressions of some of the interviews. We re-read and further discussed any transcriptions with unclear content, to make sure we understood and were familiar with the interviews.

- Coding, developing and applying the analytical framework: my main supervisor (HP) and I read and coded one of the interviews independently and then compared our codes. There were two tables for coding, a) features and b) trigger, motivation and difficulties to adopt and keep using the app prototype. The features, trigger, motivation and difficulties were extracted as the column of the table; participants’ comments were in rows of the table. 100% agreement was reached after discussion.

- Charting the features and people’s comments: the agreed framework (appendix 21: coding summary) was then used to code the rest of the transcriptions, observation notes and comments from enquiry emails and our online discussion forum. Inductive thematic analysis was used. Application features were categorised under themes, reviewed, re-categorised with reference to the 14 strategies for supporting self-management in the PRISMS taxonomy[34] and discussed iteratively with my main supervisor (HP) until agreement was reached.

- Interpretation: the results were discussed within the multidisciplinary study team, and were also presented in several medical and computer science conferences to explore any interesting ideas.
8.1.11 Quantitative data collection

There were four types of quantitative data collected in this study (see Table 19).

Table 19 The four quantitative data collections methods mapped to the outcome measurements and objectives

<table>
<thead>
<tr>
<th>Methods</th>
<th>Outcomes</th>
<th>Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Questionnaires</td>
<td>Adoption and adherence</td>
<td>1) identify features that patient and professionals would like added/excluded mapped to the taxonomy</td>
</tr>
<tr>
<td>Google Analytics</td>
<td>Adoption</td>
<td>2a) to compare the attractiveness of the app prototype to patients recruited via their practice or social media</td>
</tr>
<tr>
<td>Nurses' logs</td>
<td>Adoption</td>
<td>2a) to compare the attractiveness of the app prototype to patients recruited via their practice or social media</td>
</tr>
<tr>
<td>App usage data</td>
<td>Adherence</td>
<td>2b) to explore the adoptive and adherent features that influence patient engagement with asthma self-management</td>
</tr>
</tbody>
</table>

**Questionnaires**

Patients were asked to fill in the ‘initial’ questionnaire contained in the app, immediately after downloading and registering the app. I sent a questionnaire link to the patients after they had been using the app for 3 months to ask them to complete the ‘follow-up’ questionnaire. An outline of the questionnaires is given below, details are in Appendix 16, Appendix 17.

- **Initial (before using the app).** The questionnaire addressed a) which features attracted them and made them decide to try out an app for self-management; b) which features did they think would encourage them to keep using the app for their self-management; and c) an optional question about whether they had any special needs on reading or use of smartphone?. The list of features was extracted from our previous systematic review and the other reviews (see chapters 3 to 5). In addition, I discussed attractive and adherent features with our patient advisory group to refine the wording to be understandable for lay people. The answers were in five scale choices: 0 (strongly disagree), 1 (disagree), 2 (neutral), 3 (agree) and 4 (strongly agree). N/A (not applicable) was provided for questions such as “I would like the app to show me the daily pollen count in my area” which, if pollen was not their trigger; would not be applicable to them.
• **After 3 months.** The questionnaire asked the patient whether they were still using the app, and if so which features had motivated them to keep doing so. If they were not still using the app what did they not like about the app and what might have encouraged them to continue. The format of the follow-up questionnaire was similar to the initial questionnaire, but the list of features was different as I adapted the final questionnaire in the light of the findings of the qualitative interviews (stream A). In addition, I asked about usability of the app (listing issues raised by the qualitative interviews). I also asked if they went to their healthcare professional to assist them to fill in the action plan. If so, had they used the action plan and was it useful?

**Google analytics**

The number of unique visitors to the download instruction webpage was tracked by the Google analytics[217] over the study period. Apart from the number of unique visitors, their network ID could be viewed on the analytics’ platform by me, my supervisors and our research centre administration. Another analytics platform (bit.ly[218]) was used to verify the results on Google analytics. The date and time that the participant filled in the pre-study questionnaire and their registration time on the app were used to check the accuracy of the viewing numbers. Download rates from the three streams were extracted from the uMotif database sorted by the study ID in a password protected Excel file. The ‘campaigns’ code on the Google analytics and the activation code on the pre-study questionnaire were used to determine the way that the participants received our study information (A: practice’s invitation letter, B: nurse’s invitation and C: social media).

**Nurses’ logs**

The asthma nurses maintained a list of the number of information packs they handed out. I collected those numbers to know how many patients had taken the pack without going on to download the app prototype.

**App usage data**

I collected the users’ routine app data, such as: a) weekly usage, b) usage frequency of each of the features, c) retention rate and d) monitoring data at 30, 60 and 90 days from the database maintained by uMotif to measure adherence.
8.1.12 Data analysis

Adoption and adherence (download and usage rates)

- **Adoption:** I calculated the number of packs handed out by the nurses, and the proportion responding to the written invitation from the practice. These data were compared to the number of unique visitors to the download instructions on our project webpage, the proportion of patients who downloaded the app.

- **Adherence:** I calculated the app’s retention rate as the proportion of users who were still using the app and the individual features after 30, 60 and 90 days. Weekly usage patterns were plotted graphically.

**Questionnaires**

Responses to questionnaires were extracted to a table and analysed using descriptive statistics. The ranking and priorities of the application features were analysed for the group as a whole and then for the key sub-groups. These groups were identified by the demographic questions during the registration process (e.g. age, gender, previous ownership of a PAAP, novice smartphone user or experienced user).

A concern was that respondents would favour ‘agree’ answers. I anticipated participants would be likely to rank ‘agree’ for most of the features even if they were perceived extremely negatively because they knew they were in a research. They were aware that their answers would inform the development of future asthma apps. People tend to take ‘more’ application features as opposed to ‘less’ application features - even though they may not want that feature, however, they may think someone else may need that. This would result in including most of the features in the list. Therefore, only features scored as ‘agree’ by >50% of respondents were accepted as having been endorsed for inclusion in a future app.

8.1.13 Data interpretation

The emerging findings were presented to a multidisciplinary group (including my supervisors, colleagues from the Asthma UK Centre for Applied Research, the Patient and Public Involvement group). This presentation was in order to aid interpretation and obtain a wider perspective on the implications for development of an implementation intervention. The data were also presented at the European
Respiratory Society International Congress and the AUKCAR joint Centre meeting (with the Medical Research Council/Asthma UK Centre in Allergic Mechanisms of Asthma) for further feedback.
Chapter 9 (Phase 3) The results of the three months feasibility study and exploring the legislation issues

In this chapter, I will explain the results in detail. The results are presented in the following order to address the objectives (see section 2.2):

1. Recruitment and participants’ characteristics;
2. Perceived impact on care and feasibility of the app to support self-management (Objective 1a);
3. Attractiveness of the app prototype to patients recruited via their practice or social media (Objective 2a);
4. Adoptive and adherent features that influence patient engagement with asthma self-management (Objective 2b);
5. The features that patient and professionals would like added/excluded mapped to the taxonomy (Objective 1b);
6. Technological barriers and facilitators (Objective 3);
7. Legislative feasibility (Objective 4).

The quotes in this chapter are presented as [patient participant (stream) (ID), (age), (gender or app’s usage days)]. For example, [patient participant A1, 46-65, M] represents stream A patient participant #1, aged 46-65, male.

9.1 Recruitment and participants’ characteristics

9.1.1 Patient recruitment (streams A, B and C)

Of a combined list of over 1,757 asthma registered patients, we identified 1,115 who met our inclusion criteria: a) adults with ‘active asthma, b) able to look after their asthma themselves and c) excluding patients with severe asthma. The recruitment flow is shown in the Figure 34. The two flows in the top figures are the recruitment process starting from when the participants received our invitation from the practice or social media to download our app. The bottom figure summarises the participants’ flow from downloading the app to filling in our final questionnaires at the end of the study.
Figure 34 Recruitment flow of stream A, B, C and other unknown resources
Stream A: Of the eligible patients, 560 patients were selected randomly by GPs and had been sent an invitation pack to join stream A. 28 patients responded to the invitation by returning the expression of interest form or a letter: and two patients sent letters to explain the reason why they were not interested in participating. 15 patients were purposively sampled to be our stream A participants; two received the app’s activation code, used the app but without responding to the interview requests. Seven patients were not selected. Two patients requested or swapped to stream B.

Stream B: Patients who attended their annual review within the study period were invited to join stream B. The weekly / monthly review rates varied within the five practices: on average reviewing three to six patients (including children and some ineligible adults) per week or 30 per month with approximately a 10% patient ‘non-attendance’ rate. Within the study period, 48 patients were interested in this study and were given information packs by the nurses. Six subsequently downloaded and registered an account on the app. In total, eight patient participants were in stream B (six recruited by nurses and two swapped from stream A).

Stream C: We had 300 unique views on our project webpage about the instruction to download the app and the study information. 103 users downloaded the app, 85 passed the eligibility test and gave consent, and 82 patients registered an account on the app.

Others: There were six users who downloaded our app without visiting our project webpage, four of them passed the eligibility test, gave consent, and registered an account on the app. They may have learnt about the app’s information from other people’s mobile devices or computer, or verbally from friends or family members who participated in a conference where we had presented. One patient was specially invited by the AUKCAR Patient and Public Involvement group. These patients went through the same process as the other users and registered an account on the app. As they used the activation code (A4A-C), they were most likely not invited by medical practice. Therefore, they were grouped into stream C. In total, therefore 87 patient participants were in stream C, which became the majority of the total numbers of patient participants (87/111, 78.4%).
Of the total 111 patient participants, 98 gave us their demographics details (age, gender, action plan ownership, regular preventer medication usage, their experience on digital device and healthcare app) on the pre-study questionnaires.

9.1.2 Patient characteristics (streams A, B and C)

Age and gender

In total, 101 patient participants’ age and gender were collected (see Table 20). 26-45 years old were the majority of the population, followed by 16-25 and 46-65, a few were over 65 years old: The percentage of 26-45 in the total participants were 58.4% (59/101), others were 16-25(15/101, 14.9%) and 46-65 (24/101, 23.8%). Only three participants were 65 years old or over, they were in stream A. Female participants were over 50% in each stream with a percentage of 87.1% of the total participants (88/101).

Table 20 Age and gender of patient participants

<table>
<thead>
<tr>
<th>Age breakdown in stream A, B and C</th>
<th>65 or over</th>
<th>46-65</th>
<th>26-45</th>
<th>16-25</th>
<th>Unknown numbers</th>
<th>No. of people who gave information in questionnaire or expression of interest form</th>
</tr>
</thead>
<tbody>
<tr>
<td>A(interview), (n=15)</td>
<td>10</td>
<td>24</td>
<td>30</td>
<td>27</td>
<td>101</td>
<td>15 N/A 1 7 4 3 0 10(66.67%)</td>
</tr>
<tr>
<td>Stream B, (n=9)</td>
<td>0</td>
<td>17</td>
<td>3</td>
<td>2</td>
<td>100</td>
<td>7 2 1 3 3 0 6(85.71%)</td>
</tr>
<tr>
<td>Stream C, (n=87)</td>
<td>17</td>
<td>47</td>
<td>36</td>
<td>10</td>
<td>111</td>
<td>79 8 13 49 17 0 72(91.14%)</td>
</tr>
<tr>
<td>Total, (n=111)</td>
<td>3</td>
<td>24</td>
<td>59</td>
<td>59</td>
<td>111</td>
<td>101 10 15 59 24 3 88(87.1%)</td>
</tr>
</tbody>
</table>
Asthma action plan ownership

Of the 98 participants who provided their information, fewer than half (42/98, 42.9%) had an action plan. About a third said they had been told what to do but had not been given an action plan (38/98, 38.8%); the others had not been given any information and did not have an action plan (18/98, 18.4%).

Regular preventer medication usage

Almost all of our participants used regular preventer medication (92/98, 94%), only a few did not use regular treatment (6/98, 6%).

Their experience with digital devices

Most of our participants used smartphones (91, 93%). Apple users far exceeded the Android users (65/98, 66%; 26/98, 27%) Others used App ipad or Android table (5/98, 5%; 2/98, 2%). This distribution is in line with UK statistics 2016(Q4); there are more Apple than Android users[219].

Their experience with healthcare apps

The majority of our participants had never used any healthcare apps (80, 82%). Of the 18% who had previously used healthcare apps before our study, only a third were still using the same apps.

Social media background

Stream C contained the majority of the patient participants (88/101, 87.1%). Most of the participants in this stream were recruited from social media (307/332, 92.5%). They were the followers of the Asthma UK or the AUKCAR Facebook and Twitter, or possibly the followers of organisations or individuals who follow the Asthma UK or AUKCAR. Asthma UK had 379,000 followers in Twitter[220] and 66,665 followers in Facebook in August 2017[221]; while the AUKCAR had 577 followers in Twitter[222] in August 2017. The AUKCAR has no account in Facebook. The followers include people who care about asthma such as asthma patients, their carers, asthma researchers, charities and private healthcare companies. Updates about asthma, research recruitment and fundraising are the key contents on their social media.
Special needs

Of the 98 participants who provided their demographics information, 2% of them needed dyslexic friendly font to assist in reading or to use a smartphone. 97% did not request special assistance. 1% preferred not to say.

9.1.3 Patient characteristics (stream A) - for interview

15 participants were purposively sampled to be interviewed. All of them attended the pre-study interview and 13 of them attended the post-study interview. The reasons for not attending: i) one participant suggested they had nothing more to tell us; ii) another participant lost contact with the study. The two people were the participants who were recruited by letter from the practices. Of those who expressed their interest, they were mainly females who were over 26 year old, who had not used any healthcare apps before. From all the participants who expressed their interest, I purposively sampled 15 participants to join our interviews. Their demographics are shown in the purposive sampling matrix in the Table 21: The participants were mostly 26-46 years old, some were 46-65 years old, a few were over 65 years old and only one was 16-25 years old. They varied in whether or not they had an action plan; majority of them were without any experience with healthcare apps. Of those who had used healthcare app(s), only one was still using the same app. All of 15 participants had a smartphone or iPad. Almost half of them were using Android platform, and half were using Apple iOS.
Table 21 Purposive sampling matrix of the participants who took part in our interviews

<table>
<thead>
<tr>
<th>Participants (Age, Gender)</th>
<th>Have you been given written information?</th>
<th>Have you tried any healthcare apps before?</th>
<th>Platform</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Y</td>
<td>N</td>
<td>Yes, I am still using at least one of the healthcare apps</td>
</tr>
<tr>
<td>A1 (16-25, F)</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>A2 (26-45, F)</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>A3 (26-45, F)</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>A4 (26-45, F)</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>A5 (26-45, F)</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>A6 (26-45, F)</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>A7 (26-45, M)</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>A8 (26-45, M)</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>A9 (46-65, F)</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>A10 (46-65, M)</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>A11 (46-65, F)</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>A12 (46-65, M)</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>A13 (65+, F)</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>A14 (65+, M)</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>A15 (65+F)</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

9.1.4 Practice recruitment

The study was undertaken in five practices: four in Scotland (Lothian) and one in Oxford, who had at least one asthma nurse willing to recruit the stream B patients. 16 asthma nurses, GPs or administration managers or receptionists were interviewed. Below are the details of the five practices and the numbers of patients on their asthma registers, together with their characteristics. The practice names are identified by letters A, B, C, D and E.
<table>
<thead>
<tr>
<th>Practice</th>
<th>Descriptions</th>
<th>Asthma (characteristics)</th>
<th>Healthcare professionals who attended interview(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>A city practice with eleven GPs with and five asthma nurses</td>
<td>716 people with asthma (evenly distributed in gender but with more aging patients)</td>
<td>GP, asthma nurse, administration manager and receptionist</td>
</tr>
<tr>
<td>B</td>
<td>A suburban practice with six GPs and two asthma nurses</td>
<td>294 people with asthma (evenly distributed in gender and age)</td>
<td>Lead (asthma) nurse, asthma nurse and administration manager</td>
</tr>
<tr>
<td>C</td>
<td>A town practice with four GPs and one asthma nurse</td>
<td>329 people with asthma (evenly distributed in gender and age)</td>
<td>GP, asthma nurse and administration manager</td>
</tr>
<tr>
<td>D</td>
<td>A rural village practice group, combined with two practices. More than four GPs and two asthma nurses.</td>
<td>Over 8,400 patients but did not provide actual numbers on the asthma register at the interview because the two practices were merging their database so actual numbers were not able to be extracted. Likely to be in region of 6%, that is 504 asthma registers (considered to be approximately evenly distributed in gender and age; had a multi languages patient pool)</td>
<td>GP, asthma nurses and administration manager</td>
</tr>
<tr>
<td>E</td>
<td>A suburban practice with eleven GPs and two asthma nurses.</td>
<td>418 people with asthma (evenly distributed in gender and had more patients in 20-29 years old)</td>
<td>GP and administration manager</td>
</tr>
</tbody>
</table>

9.1.5 Characteristics of the healthcare professionals

The asthma nurses, GPs, administration managers and a receptionist who had helped by inviting patients to participate in our study, were interviewed. The nurses and GPs were trained professionals who had experience of supporting asthma patient’s self-management by offered advice and preparing paper-based action plans. The administration managers were responsible for managing the practices’ usual operations. The receptionist was the frontline staff for patients enquires and arranging the appointment bookings. Some of practices were familiar with mobile technologies, some not. A few of the healthcare professionals had experience of using activity tracking watches and apps.
9.2 Impact on care and perceived feasibility of the app to support self-management (Objective 1a)

9.2.1 The feedback from the final questionnaires

Of the 111 participants, only 23 participants submitted the final questionnaires after the 3-month trial. Two were from stream A, others were from stream C. 14 of them were still using the app while 9 had stopped. The majority of the 23 participants attended their annual review but one of the patients explained why she did not always attend:

“I have had asthma for all of my life, I feel I can manage my symptoms fairly well, if I need to go, I will make an appointment. I think the doctors/asthma nurses are busy enough already and do not need me to take up their appointment slots if it’s not necessary.” [Patient participant C1, 26-45, M]

Two of the 23 participants had discussed the action plan on the app with their nurses and one asked the nurse to fill in the action plan in their annual review. None of them had asked for an extra consultation because of our app.

14 of them thought our app could help them to improve their asthma control because this was a ‘handy tool’ which could help them to keep tracking how their asthma was doing and recognised quicker when they needed to seek medical help. Others did not think our app helped them to improve their asthma control. They suggested the reason was because their asthma was already controlled and they already knew about their asthma. The app did not actually help them to keep track of their asthma any more than they were already doing.

Nine participants were still using our app. They suggested that the reason they continued to use the app was either because: a) their asthma symptoms were troublesome, b) they needed help to manage their asthma or c) they wanted to help the research. Most of them were neutral as to whether our app helped them to manage their asthma. However, it was agreed that the health report and the 10-question monitoring ‘motif’ motivated them to keep using the app because it enabled them to show the GP or nurse how well their asthma was controlled. Ten of them suggested they would keep using it for some a few more weeks or a year or more.

Of the participants who had stopped using our app, some of them suggested that except for the asthma action plan, they didn’t need the other features provided. They
further suggested different reasons for them to stop using our app: a) when their asthma was under control they didn’t need the app, and when their symptoms were getting worse, they forgot the app; b) their app crashed on their phone; c) the app did not connect with anything. If the app could connect with alerts in their calendar or inbox, and if this particular patient’s husband could access the action plan to remind her for the decisions to be taken and if it was connected to their GP, that would be helpful.

9.2.2 The feedback from participants collected from the enquiry message box, email enquiry, our discussion forum and Asthma UK Facebook

Some participants sent their questions to our enquiry message box and email (23 messages, see Appendix 18), discussion forum (one participant, see Appendix 19) and the Asthma UK Facebook (13 participants, see Appendix 20). Their feedback echoed the thoughts of our stream A participants after the month’s trial.

Most of the participants suggested our app had raised their awareness of their asthma and helped them realise when they needed to seek help from their practice.

“Made me more aware of symptoms and identifying when I was going downhill.” [Patient participant C12, 26-45, F]

“Recognise quicker when I need to seek medical help” [Patient participant C13, 26-45, F]

“I’m far more aware of my symptoms and the impact other external factors have on them than I was before I started using the app.” [Patient participant A10, 26-45, F]

“I think it helped me realise that I needed to go back to see the doctor to get my asthma fixed.” [Patient participant A9, 26-45, M]

9.3 The attractiveness of the app prototype to patients recruited via their practice or social media (Objective 2a)

9.3.1 Adoption rate

We identified from Google analytics that 332 unique visitors accessed information about the app prototype on our recruitment advertisements. The majority (307/332, 92.5%) were from our recruitment advertisements on different online platforms or presentations in conferences (stream C). Some (19/332, 5.7%), were from the invitation letters from their practices (stream A) and a few (6/332, 1.8%) looked for
information after their nurse’s in personal invitation during their annual review (stream B). Details are illustrated in Figure 35. Of the 307 participants from stream C, the majority were from the Asthma UK Facebook and Twitter (243/307, 79.2%); some were from the AUKCAR Twitter (26/307, 8.5%), others were from the ‘organic search’ (search engine such as google) on our project name’A4A’ or the slider advertisement on AUKCAR home page (34/307, 11.1%); a few people followed up invitations/publicity in conferences (4/307, 1.3%).

However, not all people downloaded and registered on our app after reading the instruction. Users from social media were the largest group to give up without registering (221/332, 66.6%). In contrast, of those invited by practices or via personal invitation in conferences, only one of the 26 people who accessed the information did not proceed to register.

The number of registrations from stream C (invited from social media, conference and users’ organic search, n=87) far exceeded streams A & B (invited by practices, n=24) – though a small proportion of the 446,242 people signed up to these social media. The majority in stream C were from the social media (77/87, 88.5%). Users registered rapidly after the advertisements on Asthma UK Facebook and Twitter had been released. In the contrast, numerically far fewer people downloaded the app after an invitation from their asthma nurse, (6/48, 12.5%), although as a proportion of people invited this was considerable greater than social media. The 18/560 (3.2%) who registered after being sent an invitation letter from their practices will have been influenced by the requirement to consent to participating in the qualitative research. Figure 35 illustrates the registration rates.
Figure 35 The registration rates from stream A, stream B and stream C

Adoption reasons: The participants’ questionnaire responses on what made them decide to download an app to support their self-management are summarised in Table 23.

Table 23 Summary of participant’s responses on what made them decide to download an app to support their self-management

<table>
<thead>
<tr>
<th>Questions on pre-study questionnaire</th>
<th>Answers (disagree, neutral and agree, % of 98 responses)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I would download the app if I had asthma symptoms and needed help to manage my asthma</td>
<td>Disagree: 5%</td>
</tr>
<tr>
<td>I would download the app if it was recommended by my GP or asthma nurse during a consultation</td>
<td>Disagree: 0%</td>
</tr>
<tr>
<td>I would download the app if it was recommended by my GP or asthma nurse in a letter</td>
<td>Disagree: 1%</td>
</tr>
<tr>
<td>I would download the app if it was recommended by friend or family member</td>
<td>Disagree: 5%</td>
</tr>
<tr>
<td>I would download the app if it was advertised by the NHS</td>
<td>Disagree: 5%</td>
</tr>
<tr>
<td>I would download the app if it was recommended by people in a magazine, digital media such as YouTube or Twitter or Facebook etc.</td>
<td>Disagree: 19%</td>
</tr>
<tr>
<td>I would download the app if it was introduced for a research study and I wanted to help the research</td>
<td>Disagree: 1%</td>
</tr>
<tr>
<td>I would download the app if it was free</td>
<td>Disagree: 1%</td>
</tr>
<tr>
<td>I would download the app if it was recommended by the review or had a high star ranking in the Apple app store or Google play store</td>
<td>Disagree: 12%</td>
</tr>
<tr>
<td>I would download the app if it had the functions that I need</td>
<td>Disagree: 1%</td>
</tr>
</tbody>
</table>
Over 75% of participants agreed that they would download an app to look after their asthma if it was recommended by someone that they knew and trusted. It could be recommended by their GP or their asthma nurse during a consultation (93%), recommended by their GP or their asthma nurse in a letter (76%) or recommended by a friend or family member (79%). If it was advised by the NHS which was a general recommendation from a healthcare organisation they knew and trusted (such as on poster or leaflet), participants were less likely to download and tended to be more neutral (agree: 67%; neutral: 14%; disagree: 5%). If it was recommended by online media, which was a generic recommendation from a commercial organisation with no relationship to their health (such as Facebook, Twitter, YouTube, reviewers and star ranking on app store), only around 50% of participants agreed that they would download it; many others were neutral or would not download (agree: 50%; neutral: ~30%; disagree: less than 20%).

Being part of a research study increased the likelihood of people downloading the app: 90% of the participants would download the app, 7% were neutral and only 1% would not. If the app was free of charge, 87% of participants would download it, 11% were neutral and only 1% would not. If they had asthma symptoms and needed help to manage their asthma or the app had the features they needed, more than 70% of participants would download the app (neutral: less than 20%, disagree: less than 10%).

Other reasons which eight participants entered in the free text box were: ‘help monitor’, ‘measure’ and ‘manage’ their asthma (6/8); the app was ‘handy’ (1/8); and ‘because the app was promoted by Asthma UK in the social forum’ (1/8).

9.3.2 Practice: exploring the low adoption rate via consultations

Numerically, the adoption rate from the nurse ‘in-person’ invitations was far lower than the social media despite most of the participants responding in the questionnaire that a personal invitation from their healthcare professional was the most effective means to trigger them to adopt an asthma app. I therefore, explored recruitment in the final interviews with the nurses and found out some of the challenges.

- Recruitment for the study took place over the Christmas and New Year holiday which was an ‘off peak’ time for asthma annual reviews. Fewer
patients attended the consultation during our study time compared to the usual months.

- The average number of asthma patients attending for an annual review was approximately around 20 to 30 per month, with approximately 10% of patients not attending. Therefore, the total number of eligible patients that we can reach by this approach was relatively low.

- Most eligible patients welcomed the invitation. Many of them took the information pack and showed interest in downloading the app (see Table 24). We have no way to trace why some didn’t adopt the app after the consultation. Nurses, however, shared some thoughts from their practical experience: a) a positive reaction could be a ‘polite response’ from patients who did not want to disappoint the nurses in person; b) patients may forget about downloading the app after they went home; c) maybe they had experienced some difficulties in downloading the app and rather than carry on and ask advice, they just gave up. Therefore, the nurses suggested a person to sit in the practice (maybe next to the consultation room or waiting room) to assist patients to set up the app would be of advantage.

Table 24 Numbers of patients who showed their interest in the app during the nurse consultation

<table>
<thead>
<tr>
<th>Practice</th>
<th>Total no. of packs delivered within different days/no. of days to invite patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Practice A</td>
<td>14/103 days (X’mas and new year holidays in between)</td>
</tr>
<tr>
<td>Practice B</td>
<td>15/104 days (X’mas and new year holidays in between)</td>
</tr>
<tr>
<td>Practice C</td>
<td>6/66 days (after X’mas and new year holidays)</td>
</tr>
<tr>
<td>Practice D</td>
<td>6/39 day (after X’mas and new year holidays)</td>
</tr>
<tr>
<td>Practice E</td>
<td>7+/116 (2 asthma nurses delivered packs- 1 asthma nurse lost contact)</td>
</tr>
</tbody>
</table>
9.4 The adoptive and adherent features that influence patient engagement with asthma self-management (Objective 2b)

I followed the Fogg behaviour model (trigger, motivation and ability) to explore the features to influence the patient engagement.

9.4.1 Using theory to understand the triggers, motivation and ability leading the patient to adopt the app

*Adoption: trigger*

The adoption trigger for participants was pre-set events that asked patients to ‘adopt’ the app. For stream A participants, it was the practice’s invitation letter; for stream B participants, it was the asthma nurse’s verbal invitation; for stream C, it was our advertisements on social media, presentation and indirect recommendations from people who had heard about the app.

*Adoption: motivation*

Three main themes of motivation were identified in the interviews: i) wanting to help research, ii) wanting to have better health outcomes, and iii) just for curiosity. Some of the participants had more than one of those motives to trigger their adoption. Their motivations are illustrated in Figure 36.
Question: What made you decide to try out the app?

- "It could be helpful for the medical, you know studies or something so to advance their work." [A3, 26-45, F]
- "(I) want to try and make better and progress knowledge." [A4, 65+, F]
- "I'm more interested in passing on my experience as an asthmatic to help the next generation of asthmatics make it easier." [A7, 65+, M]
- "I want to help myself (improve asthma)"  "you're contributing to something and you're making other lives better by doing this..." [A2, 46-65, F]
- "I suppose just too maybe recognise... recognising when I need to use the blue inhaler, the reliever. Just to make sure I was managing my symptoms." "Also just to help the study" [A5, 26-45, F]
- "I just thought it would be useful to monitor that to see if there's a pattern or just to manage it more effectively." [A6, 26-45, F]
- "Partly for my interest and partly because it helps you (your research)" [A1, 46-65, M]
- "I thought I'll try and help you out. Curiosity." [A12, 65+, F]
- "I wanted to help out (the research)." "I thought it's an interesting idea to use and app to help you monitor your disease status." [A13, 46-65, M]
- "Curiosity is my main motivation." [A7, 65+, M]
- "I was interested in knowing more about it (asthma)... mainly just trying to make sure I stay on the medication." [A14, 16-25, F]
- "Suffering (wake up most nights because of coughing) has made me interested in this app." [A15, 26-45, M]
- "I'm interested in mobile learning." "It's easier to track down my record on the mobile." [A8, 46-65, F]
- "I thought let me try and track it and ... if I was seeing any benefits to doing it at a particular different time of the day." [A9, 26-45, M]
- "The motivation is to see if I can improve it, not to a level that I'm not prescribed inhalers anymore but to a better level." [A10, 26-45, F]
- "I think as a reminder (for medication)...I can tell when I've missed that so I can tell the difference in my asthma." [A11, 26-45, F]

Note: the pointer on overlapped areas meant participants had both of those motivations to drive their adoptions.

Figure 36 Motivations to adopt our app
To have better health outcomes such as to improve their asthma by monitoring and being reminded of their medication was the main motivation to drive participants to adopt our app.

“I just thought it would be useful to monitor that (my asthma symptoms) to see if there’s a pattern or just to manage it more effectively.” [Patient participant A6, 26-45, F]

“Suffering (wake up most nights because of coughing) has made me interested in this app.” [Patient participant A15, 26-45, M]

“I think as a reminder (for medication)...I can tell when I’ve missed that so I can tell the difference in my asthma.” [Patient participant A11, 26-45, F]

To help research was the motivation for some of our participants.

“it could be helpful for the medical, you know studies or something so to advance their work” [Patient participant A3, 26-45, F]

“(I) want to try and make better and progress knowledge” [Patient participant A4, 65+, F]

“I’m more interested in passing on my experience as an asthmatic to help the next generation of asthmatics make it easier.” [Patient participant A7, 65+, M]

Curiosity about what an app could do for people with asthma was the motivation for a few participants.

**Adoption: ability**

Patients downloaded our app by themselves after they had received our activation code. Most of them downloaded the app, filled in the questionnaires and used the app successfully. Some of the older patients needed some assistance on the download. Two patients aged 65+ sent enquiry emails to me. The problems they encountered were: i) being unable to find the app prototype on the iPad, ii) confusion with Google payment setup for the app and iii) insufficient memory on their mobile phone. They were able to download the app after my e-mailed suggestions. Another patient, in the 46-65 age group, who was less confident with technology, sought help from her son to download and setup the app.

“Well I think that somebody younger would get it straight away but as I say I’m not very good with these things.” [Patient participant A2, 46-65, F]
9.4.2 Exploring why participants didn’t try out our app?

I received two reply letters from potential participants at the beginning of our study to explain why they decided not to take part. In addition, some participants did not use any of the features on our app during the study. Therefore, I further explored the reasons in their final interview.

There were three main reasons they suggested:

a) they knew how they felt and knew what to do when their asthma was getting worse, therefore, they did not need a tool to record their symptoms and tell them what to do next. They wanted to see more advanced app’s features which told them something that they didn’t know such as their exact triggers;

b) they were busy and their asthma was under control

c) they had no smartphone, therefore, they could not join our study

“I don’t feel the need that I’ve got to record anything like that, have a diary going because I know how I feel at a given time.” [Patient participant A12, 65+, F – reason a]

“I think the reason is that as you would have seen I’m exceptionally busy and so I tend to, I don’t use apps much so in fact I probably only use about four in total... My asthma has been completely under control... there’s no reason why you shouldn’t just live a normal life and keep myself active” [Patient participant A13, 46-65, M – reason b]

“I do not have any of the equipment needed for this study and therefore am not suited to take part” [U1(not attended) – reason c]
9.4.3 Adherence rate

Adherence fell over time. Most of the participants had stopped using our app prototype after 30 days. Only 28 participants were still using our app on the 30th day. The total number of users was further reduced to 17 and 6 on the 60th day and 90th day respectively. Participants from social media were the majority of the total users over the 90 days. However, their usage rate dropped rapidly in the first 30 days (from 77 to 13 participants; reduced by 83.1%). The usage rate from those invited by practices also declined, but less rapidly than in the social media group (stream A: from 16 to 10 participants, 37.5%; stream B: from 8 to 3 participants, 62.5%). The adherence rate of our app is summarised in Figure 37 and Table 25. The retention pattern in the practice-recruited patients was similar to that in general app usage, in which 39% of users gave up the app after 30 days, only 26% and 20% of users continue to use an app after 60 and 90 days[223].

![Figure 37 Adherence rate of the app over time](image)

<table>
<thead>
<tr>
<th>Sources</th>
<th>No. of days</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Stream A</td>
<td>16</td>
</tr>
<tr>
<td>Stream B</td>
<td>8</td>
</tr>
<tr>
<td>Stream C: social media</td>
<td>87</td>
</tr>
<tr>
<td><strong>Total no. of people</strong></td>
<td>111</td>
</tr>
</tbody>
</table>

Table 25 Adherence of the app from different steams
9.4.4 Using theory to understand the triggers, motivation and ability leading the patients to adhere to using the app

Adherence trigger

**Question: What triggered you to go back to the app?**

![Diagram](Figure 38 A summary of how participants used the notification and their usage on app)

Pop up notification is commonly used on apps to bring users back to the app. So, did it help to bring patients back to our app?

A pop up push notification was set at 18.00 everyday by default. This was a trigger event to remind participants to get back to the app. Figure 21 summarised how participants used the notification and their usage of the app. Four of the participants disabled this feature. The reasons they gave were: a) they switched off the reminder by mistake and did not know why it was disabled; b) they didn’t want to use the app, therefore, they switched off the reminders; and c) they didn’t like notifications, therefore it suited their lifestyle to switch off notifications on their phone (except phone calls and SMS). The majority of participants, however, kept the notifications on their app:
Some of them thought it was a useful reminder and got back to the app immediately after the notification.

“A reminder comes on my phone and then if I’m working night shift and I’m sitting there then I have time that I’ll fill it out but if I’m off and I’m busy then I tend not to do it.” [A5, 26-45, 48]

Although some participants got back to the app because of the notification, others ignored the reminder. Some never bothered about reminders, or they were busy, or they had nothing to input in the app, or they forgot to do it after seeing the notification.

The patients’ observations are summarised in Figure 38: The four participants who had disabled the notifications had all stopped using the app within 60 days. If participants thought the notification was ‘useful’, the notification might successfully bring them back to the app and encourage them to use the app for longer.

**Adherence motivation**

Most of the participants stopped using our app within 30 days, only a few were still using it after 60 and 90 days. I explored the motivations driving them to keep using our app. ‘If they had stopped using our app, what did they think would motivate them to keep using an app to support their asthma self-management?’ Participants suggested that perceived benefits or encouragement from GP, asthma nurse or researcher would motivate them to at least keep the app on their mobile devices, use it when their symptoms were getting worse or when they needed help on managing their asthma. There were four main benefits that they would like to see: i) health benefits, ii) practical help with their self-management, iii) research benefits and iv) financial initiatives. Figure 39 summarise these motivations related to the number of usage days by the participants.
Figure 39 A summary of what would keep participants to keep using an app and their usage in this study

Most of the participants who had kept using our app for at least 30 days suggested that health benefits were the motivation to keep them using the app to support their asthma self-management. The health benefits included:

a) helping them understand more about their asthma, making them aware of what caused their asthma and how asthma had affected them, to enable them to make sure they were under control or eventually to reduce symptoms and medications.

“She (asthma nurse) would be able to pinpoint days where I say that I wasn’t feeling so good and my breathing wasn’t very good or walking or on housework or something like that and she would be able pinpoint what was asthma and what was just arthritic pain.” [Patient participant A2, 45-65, usage: 68 days]

“I can keep a track on maybe how, in linking what’s going on in life versus what triggers your asthma...to educate people on their asthma I think yeah it is a good thing.” [Patient participant A5, 26-45, usage: 48 days]

“(I want to see) things that may affect my asthma.” [Patient participant A7, 65+, usage: 84 days]
“That’s the problem I don’t understand enough about asthma despite having it all my life to actually know, like this app tries to decipher what to do and what triggers things.” [Patient participant A15, 26-45, usage: 0 days]

b) as a memory aid to remind them about medication.

“I would use the app more as a memory aid for all aspects of my asthma, when to take the medication“ [Patient participant A4, 65+, usage: 129 days]

“Even I know my symptoms, even I know this is what I need to do when I have this or have that...but that you may forget later I think it’s still worth it. “[Patient participant A8, 46-65, usage: 99 days]

“sometimes I go to my bed and forget (taking medication) but because that makes a noise it reminds me that I have to take it so I like that part.”[Patient participant A11, 26-45, usage: 11 days]

c) helping adherence to exercise

“(the missing log) it’s made me feel a little bit guilty so it’s then motivated me to work out the next day.“[Patient participant A10, 26-45, usage: 55days]

d) as a psychological care support

“I think by just putting it into the app and just saying I feel a bit down today it sort of raises my spirits. (laughs)...it’s like a support in a way because nobody ever comes into the house and says how are feeling [Name]? “[Patient participant A2, 46-65, usage: 68 days]

Some of the participants suggested the action plan and logging a peak flow on the app had motivated them to keep using the app because it prevented them losing the paper action plan and saved time on handling paper-based logs.

“it’s less fear to lose it...I go very badly probably I will look at it and see what it is suggesting."[Patient participant A3, 26-45, usage: 58days]

“I’ve got my phone all the time using the app is easier for me. “[Patient participant A9, 26-45, usage: 52 days]

“it looks quite easy to use and put in all my medication and my action plan on it just so it’s all in one place will be useful. ”[Patient participant A14, 16-25, usage: 0days]

“previously all you had was the big sort of fold out document and you would take your peak flow.. it’s very time consuming and you let it slide...whereas you’re on your phone all the time... the app is really straight forward to use.” [Patient participant A10, 26-45, usage: 52days]
A few participants suggested financial initiatives such as discount vouchers would encourage them to keep using the app.

“you can collect some points and you can transfer it, you can use some points for shopping or maybe discount vouchers or if you collect some points by using the app regularly then you could unlock some games or things.”[ Patient participant A8, 46-65, usage: 99 days]

“If there was some sort of pay off then I would probably, it would remind me and encourage me to use it more.”[ Patient participant A10, 26-45, usage: 52 days]

If the app was part of a research programme, this would also motivate some of the participants to keep using it. However, only one of those who suggested this reason actually used our app more than 90 days; others were less than 60 days and one had never used the app. Their reasons were further explored and are reported in the section 9.4.3: exploring logging patterns.

Some participants who stopped using our app within 30 and 60 days, suggested in-person support such as the healthcare professionals or a researcher would motivate them to keep using the app.

“It has to be someone to push me” [Patient participant A3, 26-45, usage: 58 days]

“I had good intentions after our last meeting and I did put in some information and I was looking at the data that you would put in every day” [Patient participant A6, 26-45, usage: 20 days]

“She (nurse) was probably really important because I didn’t have a clue and I probably never took asthma very seriously.” [Patient participant A11, 26-45, usage: 11 days]

Ability

Most patients were able to use the app prototype by themselves, though some of them needed assistance at the beginning of its use. These patients ranged in age from 26 to 65+. They felt it was complicated to begin using the 10 question monitoring ‘motif’: they wondered how to save the answer, and the meaning of the ‘motif’ questions and healthcare graphs. Other difficulties, mentioned by the older users were using the segment flower to enter and save data, setting up the reminder alarm and rotating the screen to enlarge the healthcare graph.
Exploring logging patterns

Participants logged their data at different time intervals: daily, weekly and monthly. In the final interviews with the stream A participants I explored if they had any preferences on how often to log data and what made them stopped logging.

Overall, participants did not have consistent preferences to log data on daily, weekly or monthly basis.

Most of the participants logged data irregularly on a weekly and monthly basis. They suggested they would like to spot any unusual patterns on their log data to understand more about their asthma, therefore, they keep logging. However, when they felt their asthma was well controlled, they stopped logging because they felt it was ‘boring’, especially when they saw nothing but a flat line. Some suggested other reasons for stopping: a) they thought the healthcare professionals was not interested in their logs, therefore logging was meaningless; b) they were on holiday without internet access, thereby preventing them from entering data promptly; c) the 10 questions in the segments didn’t mean anything to them, so they did not know what to fill in, therefore they stopped logging.

Some of the irregular logging participants further suggested they sometimes struggled to keep logging because the 10 questions monitoring ‘motif’ were not totally applicable to them. They could not disable the irrelevant questions which discouraged them from logging their data. However, they knew they were in a research programme, so some kept logging until the end of the study.
9.5 The features that patients and professionals would like added/excluded mapped to the PRISMS taxonomy (Objective 1b)

9.5.1 Patient participants’ rating of the different features

The participant’s responses on what would they like to see in an app to support their self-management are summarised in Table 26.

Table 26 The participants’ responses on what would they like to see in an app to support their self-management (Note: shaded are the ‘baseline’ features that more than 50% of participants in the initial questionnaire supported. Features which had over 90% supports are highlighted in bold.)

<table>
<thead>
<tr>
<th>Application features</th>
<th>Participants (n=98)</th>
<th>Disagree</th>
<th>Neutral</th>
<th>Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I would like the app to tell me about how to manage my asthma (e.g. how to use my inhaler, use of action plan, tips on managing my asthma etc.)</td>
<td>3(3%)</td>
<td>9(9%)</td>
<td>86(88%)</td>
<td></td>
</tr>
<tr>
<td>I would like the app to have an electronic diary that allowed me to log my asthma symptoms or peak flow, medication use and when I had seen my doctor or nurse</td>
<td>1(1%)</td>
<td>6(6%)</td>
<td>91(93%)</td>
<td></td>
</tr>
<tr>
<td>I would like the app to remind me to log my symptoms in the diary</td>
<td>3(3%)</td>
<td>6(6%)</td>
<td>89(91%)</td>
<td></td>
</tr>
<tr>
<td>I would like the app to warn me if my asthma was getting worse or if I was having an attack</td>
<td>3(3%)</td>
<td>4(4%)</td>
<td>91(93%)</td>
<td></td>
</tr>
<tr>
<td>I would like the app to show my symptoms scores and daily peak flow on a 3 colour graph (green, amber and red)</td>
<td>2(2%)</td>
<td>7(7%)</td>
<td>88(90%)</td>
<td></td>
</tr>
<tr>
<td>I would like the app to have an action plan that could tell me what to do if my asthma was getting worse</td>
<td>1(1%)</td>
<td>4(4%)</td>
<td>93(95%)</td>
<td></td>
</tr>
<tr>
<td>I would like the app to remind me to take my regular medication</td>
<td>10(10%)</td>
<td>16(16%)</td>
<td>73(74%)</td>
<td></td>
</tr>
<tr>
<td>I would like to be able to order my repeat prescriptions using the app</td>
<td>8(8%)</td>
<td>26(27%)</td>
<td>64(65%)</td>
<td></td>
</tr>
<tr>
<td>I would like to share my app dairy with my GP/asthma nurse</td>
<td>1(1%)</td>
<td>11(11%)</td>
<td>85(87%)</td>
<td></td>
</tr>
<tr>
<td>I would like the app to remind me when I am due to see my asthma nurse or GP for a routine review</td>
<td>3(3%)</td>
<td>16(16%)</td>
<td>78(80%)</td>
<td></td>
</tr>
<tr>
<td>I would like the app to have a panic button to alert friend or healthcare expert who can get emergency help</td>
<td>10(10%)</td>
<td>30(31%)</td>
<td>58(59%)</td>
<td></td>
</tr>
<tr>
<td>I would like the app to remember when I had symptoms, cross reference with environmental factors and tell me about possible triggers for asthma</td>
<td>0(0%)</td>
<td>4(4%)</td>
<td>94(96%)</td>
<td></td>
</tr>
<tr>
<td>I would like the app to help me to relax such as providing stress free exercises or playing music</td>
<td>15(15%)</td>
<td>36(37%)</td>
<td>47(48%)</td>
<td></td>
</tr>
<tr>
<td>I would like the app to have some games about asthma (avatar or virtual pet or simple shooting game etc.)</td>
<td>44(45%)</td>
<td>29(30%)</td>
<td>25(25%)</td>
<td></td>
</tr>
<tr>
<td>I would like the app to connect with my inhaler to log the number of doses I have taken and to remind me when the medication is running out</td>
<td>13(13%)</td>
<td>20(20%)</td>
<td>65(66%)</td>
<td></td>
</tr>
<tr>
<td>I would like the app to help me to achieve my activity goals as well as watching my asthma condition during sport</td>
<td>11(11%)</td>
<td>21(21%)</td>
<td>67(68%)</td>
<td></td>
</tr>
</tbody>
</table>
| I would like the app to help me watch my weight as well as my asthma condition [N/A: 3(3%)]
| I would like the app to alert me when the pollen count in my area is high [N/A: 1(1%)] | 6(6%)              | 8(8%)    | 82(84%)|
I would like the app to show me the daily pollen count in my area [N/A: 1 (1%)]

<table>
<thead>
<tr>
<th></th>
<th>6(6%)</th>
<th>13(13%)</th>
<th>78(80%)</th>
</tr>
</thead>
</table>

I would like the app to help me to quit smoking as well as watching my asthma condition [N/A: 65 (66%)]

<table>
<thead>
<tr>
<th></th>
<th>14(14%)</th>
<th>17(17%)</th>
<th>4(4%)</th>
</tr>
</thead>
</table>

The features on the list were agreed by more than 50% of the participants. They were the features that participants thought would be attractive when they first downloaded the app. Of these ‘baseline’ features, some had the support of >90% of participants. These features were related to self-management: a) logging asthma symptoms or peak flows on a green, amber and red, b) a warning that their asthma was getting worse, c) provision of an action plan to tell them what to do if their asthma deteriorated or they were having an attack, and d) sharing their data with practices. Others desirable features included; e) showing the pollen count, f) cross referencing their symptoms with environmental factors and g) telling them about possible triggers for asthma.

There was one feature which was scored negatively (45%): the idea of having some games about asthma (avatar or virtual pet or simple shooting game etc.) on the app.

Three features had mixed assessments by the participants, with similar numbers of participants scoring ‘agree’ and ‘neutral’. These features were: i) having a panic button to alert a friend or healthcare expert who could get emergency help; ii) having relaxing elements on the app such as stress free exercises or playing music; and iii) helping them watch their weight as well as their asthma condition.

The feature of helping them to quit smoking was not applicable to most of our participants (68%).

9.5.2 Features usages

Seven features were implemented in our app. They were the a) 10 question ‘motif’, b) asthma action plan, c) diary, d) medication, e) lung function, f) medication reminder and g) task reminder.

The most used feature was the 10-question monitoring ‘motif’ (98/111), followed by the asthma action plan (42/111) and diary (40/111). Medication and lung function were used by some users (medication: 36/111; lung function 28/111). Medication and task reminders were the features that were used least by participants (medication reminder: 13/111; task reminder: 2/111). These data are summarised in Table 27.
<table>
<thead>
<tr>
<th>Features*</th>
<th>No. of users (used)</th>
<th>No. of users (not use)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. 10 question monitoring ‘motif’</td>
<td>98</td>
<td>13</td>
</tr>
<tr>
<td>2. Asthma action plan**</td>
<td>42</td>
<td>69</td>
</tr>
<tr>
<td>3. Diary</td>
<td>40</td>
<td>71</td>
</tr>
<tr>
<td>4. Medication (the details of their medications)</td>
<td>36</td>
<td>75</td>
</tr>
<tr>
<td>5. Lung function</td>
<td>28</td>
<td>83</td>
</tr>
<tr>
<td>6. Medication reminder</td>
<td>13</td>
<td>98</td>
</tr>
<tr>
<td>7. Task reminder</td>
<td>2</td>
<td>109</td>
</tr>
</tbody>
</table>

Note: *Feature were ranked by the numbers of users (top: most people); ** Asthma action plan was the Asthma UK action plan (source: https://www.asthma.org.uk/advice/manage-your-asthma/action-plan/)

Table 27 A summary of the features used by participants

Of those who had used the 10-question monitoring ‘motif’, 18.4% (18/98) only logged once within the study period. Others logged at different daily, weekly or monthly time intervals.

Of the 111 participants, eleven of them did not use any of the features on the app. Of those who provided their demographic information (9/11): they could be any age (8/9 were 26 years old or over) and were recruited from social media. All of these nine participants used regular preventer medication and had never used any healthcare apps before our study; they were spread between genders, with/without an action plan and were the users of different mobile platforms.

**Action plan completion**

As for the action plan, of those who had provided their demographic information to us (n=98), 56 participants were without a written action plan before our study, 20 of the 56 participants had adopted our action plan on the app in our study. Of the 20 patients, nine told us how they filled in the action plan (final questionnaires: 5; interview: 4) as follows: a) five of them filled in the action plan without consulting their asthma nurses or GPs, b) three asked their asthma nurse to fill in a paper-based action plan and they transferred the data on the app by themselves, and c) only one filled in the action plan on the app with the asthma nurse in the routine review. Of the 42 participants who had owned a paper-based action plan before our study, 18 of them had transferred their data from paper to our app. In total, the ownership of
action plans increased from 43% (42/98) to 63% (62/98), as a result of the study. Details were showed in the study. Details were showed in the Table 28.

<table>
<thead>
<tr>
<th></th>
<th>Filled in action plan on app</th>
<th>Didn't fill in action plan on app</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before: no action plan (n=18)</td>
<td>5 (26.32%)</td>
<td>13 (72.2%)</td>
</tr>
<tr>
<td>Before: no action plan but have been told what to do (n=38)</td>
<td>15 (39.47%)</td>
<td>23 (60.53%)</td>
</tr>
<tr>
<td>Before: had an action plan (n=42)</td>
<td>18 (42.85%)</td>
<td>24 (57.14%)</td>
</tr>
<tr>
<td>Total response in the initial questionnaires (n= 98)</td>
<td>38 (38.78%)</td>
<td>60 (61.22%)</td>
</tr>
</tbody>
</table>

Table 28 The numbers of participants who used an action plan on the app and their ownership of paper based action plans

**Keeping a diary and medication reminders**

Low adoption and non-adherence to (not using) the free-text diary, and medication reminder was identified. Free-text diary was a module that allowed patients to input free-text and pictures for their daily activities. Most of the participants stopped using the diary within 30 days, a few stopped using it after 60 days, a few keep using it over 90 days and some did not try the diary at all. Stream A participants suggested some reasons for not using the diary. Two main reasons were: i) they were not sure how a diary could help their asthma management and ii) they were not the sort of person who used a diary.

“I wasn’t sure what to actually put in it would be helpful” [Patient participant A7, 65+, M]

“I’m not really that kind of person who keeps the record of things that I do.”

[Patient participant A8, 46-65, F]

One participant, however, liked the diary very much and frequency used it to record her emotions because she thought it helped to relief the stress and raised her spirits.

“I think by just putting it into the app (diary) and just saying I feel a bit down today it sort of raises my spirits. (laughs)” [Patient participant A2, 46-65, F]
Most of the participants had not used the medication reminders. I also explored the reasons for not using the medication reminders with patients in stream A in the final interview.

Most of them suggested that taking medication had become part of their routine. For example, they used to put their preventer inhalers near their toothbrush, their bedside or where they could spot them easily. Therefore, they did not need a reminder. One participant wanted to try this reminder and set the alarm, however, the alarm was not set properly which he didn’t realise and eventually forgot about this feature. Another participant stated that she did not know there was a medication reminder on the app, therefore, she didn’t try it.

“I don’t/ never forget.”[Patient participants A3, 26-45, F; A4, 65+, F; A6, 26-45, F and A7, 65+, M]

“I’m quite good (to take medication regularly) to be honest I don’t think I need that.”[Patient participants A5, 26-45, F and A10, 26-45, F]

“I used to keep my inhaler next to my toothbrush so it was fine.”[Patient participant A5, 26-45, F]

Professional’s perceptions of using an app to support asthma self-management

The healthcare professional’s feedback on two aspects of using apps to support self-management: for the patient and within their consultation. Their thoughts are summarised in Appendix 21.

Using apps to support self-management: for the patient

Most of the professionals suggested that an app would encourage more patients to manage their asthma, especially for young adults because they always had their phone and they were familiar with apps. Some suggested this familiarity empowered patients to undertake better monitoring of their asthma. They also believed the app could prevent patients losing their action plan, as well as improving their knowledge about their asthma. If patients input their asthma condition on an app and reviewed it regularly with their GP or asthma nurse they could learn more about what caused their asthma and what impact the asthma had on them.
“I mean I think it’s a great idea to use a mobile phone app, especially with the younger demographic I think that’s the way the world work” [GP 03]

“it gives people control and they like control, they like to feel they know what’s going on rather than having always having to wait on somebody else doing it for them.” [Administration staff 03]

In contrast, most of the healthcare professionals suggested older adults may have difficulties using an app. A healthcare professional worried that those patients who did not have smartphones or were not familiar with apps, may feel they had been ‘abandoned’ by the healthcare system. Some practices also worried about non-adherence to using the app: busy patients, or patients who didn’t take care of their health, may not invest time to try out an app. Even if such patients tried, they may soon get bored and stop using it. A few practices suggested an app may raise concerns about data confidentiality; patients may worry about their logs being stolen or used by unauthorised parties.

“It’s not suitable for those that don’t use a phone and I would say probably there will be issues around the elderly with that because it’s not something that they would be able to manage.” [Asthma nurse 01]

“I think some of them will start off using it but will get bored after a while.” [Asthma nurse 06]

Using apps to support self-management: within the consultation

Poor attendance at annual reviews was a problem in some of the practices. The working age group had the highest non-attendance rate amongst all the patients. ‘Busy’ was the commonest reason that the practices’ nurses mentioned when they were explaining the high non-attendance rate of the asthma patient group. Some practices suggested the app should be able to: a) monitor the patient’s condition, b) remind them to take their medication, c) advise patients to adjust their medication and d) prompt them to arrange a consultation if / when their symptoms were getting worse. In addition, apps could provide easy modes of consultation and reviewing patients’ logs, as well as offering online booking for face-to-face consultations. The health professionals believed this would reduce the need for nurses to make annual review appointments for those busy and well controlled asthma patients.

“I think in terms of the practice time I think it potentially could avoid practice routine, several routine practice visit.” [GP 02]
However, some healthcare professionals suggested this could not reduce appointments unless the app would be able to check a patient’s inhaler technique which currently the nurse usually checks in the annual review.

“one of the points of the face to face consultation is to assess your technique so if you could do that all with video that would save them having to come along.” [GP03]

In addition, some healthcare professionals worried about extra time in the consultation which would be needed to solve the technical problems caused by an app.

“When something goes wrong with the app they lose their password or they can’t get in or whatever who runs the problem solving issue? Is that expected to be the nurses in the practice as well? (if administrators to help) No thank you. I mean we have enough trouble with our own IT without bringing in something else where we have to manage something that’s not ours, you know it’s an outside app. We don’t run our own IT the health board run our IT, we do day to day problem solving but all our IT is run by the health board so to bring in an external bit and expect us to manage it is maybe a big ask. [Administration staff 03]

9.5.3 Patients’ use of action plans and perceptions of self-management

Of the patients attended the interviews, they described how they used the action plan (summarised in Figure 40).

Figure 40 A summary of how participants responded to our digitised action plan and what they think about an asthma action plan
Half of the stream A participants had a paper based action plan before our study, only a few of them transferred their data to our digitised action plan. The patients who did not transfer their data were also the participants who said they ignored their paper based action plan; they thought they didn’t need an action plan. The reasons for this view were a) they thought they knew what to do when their asthma was getting worse; b) their asthma was well controlled, so there was no chance for them to use their action plan and c) the action plan was too generic; d) the best peak flow reading was wrong on the action plan.

“there’s no advantage to me in using them... I know what I do every day...I just take a preventative puff that’s all” [Patient participant A1, 46-65, M]

“it’s not something that I have to refer to ever really.” [Patient participant A10, 26-45, F]

“it was filed so well I couldn’t find it...my asthma is so mild it is quite common sense...I’ve never had an actual asthma attack so it’s never something that’s kind of at the top of my radar anyway.” [Patient participant A6, 26-45, F]

“It’s a leaflet. I mean it might be quite useful it would tell me what to do if something went wrong but it’s telling me exactly the same thing as it tells 20 million other people so it’s not my action plan.” [Patient participant A1, 46-65, M]

“it’s not relevant to me” [Patient participant A5, 26-45, F]

For those participants who had transferred their data, one thought an action plan was a useful guide in an emergency, so he wanted to have one on his phone. However, another patient had been given a best peak flow on a new action plan with which he didn’t agree; therefore, he ignored the plan.

For other participants who did not have a paper-based action plan before the study, some requested a paper-based action plan from their practices and transferred the data with nurses or by themselves. They thought it was a “learning tool” to help them to know more about their asthma, so they would use it when they forgot about the medication adjustment or when their symptoms were getting worse.

“I didn’t know I could use my blue inhaler up to 10 times. I thought I could only use it twice at any one time. I now know that I can use it, and I think it’s on here actually on the action plan...it’s actually instructive it tells you what to do. If I wasn’t sure of what I had to do I would get that out ” [Patient participant A4, 65+, F]
“I just use that as and when required.” [Patient participant A9, 26-45, M]

Some didn’t request a paper based action plan or ask nurses to fill one in directly on their app. They thought they would not need it because they already knew what to do. Another participant wanted to had an action plan either on paper based or on app, however, he/she was not able to contact the nurse after several attempts, resulting in no review and no action plan completed by the end of the study.

“there’s no need for me to read this because I know what I do every day” [Patient participant A3, 26-45, F]

“I think it’s because my asthma has been fine...the reason why I haven’t got to doing an action plan is it just hasn’t been high priority for me.” [Patient participant A13, 46-65, M]

Those participants, who didn’t use action plans, suggested they had a workable plan for themselves in their mind: to take preventers regularly, take puffs before exercising, asking their GPs for repeat prescription or contacting them in an emergency. If further help needed, called ‘999’.

9.5.4 Features of the app related to the PRISMS taxonomy

The PRISMS taxonomy describes 14 components to support long term conditions (see section 1.2.2). To further explore the acceptability to our participants of different supporting features I mapped the perceptions of our patients and professional participants, to the components in the PRISMS taxonomy. Of the 14 self-management support components, eight were represented by features in the app prototype. Three of them were viewed positively by both patients and professionals. These were: provision of/agreement on specific clinical action plans and/or rescue medication; provide monitoring of patient’s conditions with feedback; and provide training/rehearsal for everyday activities. The application features related to these components are: a digitalised asthma action plan; logging symptoms, peak flow and medication use; cross reference of asthma logs with environmental factors to find out possible triggers and high pollen count alert. Details are discussed below.
PRISMS taxonomy components: A) Information about condition and/or its management and B) Information about available resources

- Feature on the app prototype: provide links about asthma management information and environmental information such as pollen count and temperature

The majority of patients wanted to have asthma management information and environmental information on the app. The interviewed patients, further suggested that the pollen level should be on the app interface instead of providing links to the pollen count website.

"there was maybe like a pollution count in where you live, like Edinburgh or Glasgow. And also maybe I tend to get a tightness in my chest when it’s very cold so weather, a cold day be careful take your medication with you"

[Patient participant A8, 46-65, F]

A GP thought providing information support was ‘a good thing’.

PRISMS taxonomy components: C) Provision of/agreement on specific clinical action plans

- Feature on the app prototype: Asthma UK action plan (with advice but without prompts)

Over 90% of patients responding to the initial questionnaire were positive about having an action plan on the app but felt that the digitalised action plan needed to be more ‘intelligent’ such as auto updating after practice consultations (e.g. the best peak flow values and ‘puffs’ of inhaler will be updated on the app if they have been changed after consultation), notifying the patient (or their practice) when symptoms was getting worse and giving advice. Of the interviewed patients, one suggested to have a reminder which could be sent to their partner/carer to remind him to fill in the action plan.

“As I mentioned maybe like a direct link with like a GP record and they could just collect the data from my app because sometimes they ask and you have to keep the record of the peak flow and then just bring it to the next asthma clinic.”

[Patient participant A8, 46-65, F]

Of the 111 users, 42% of users used the action plan in the app prototype. The interviewed patients felt that the app prototype did not sufficiently encourage patients to use the action plan. However, the app did provide an opportunity for some patients, who did not already have an action plan, to start one.
The majority of healthcare professionals were positive about implementing an action plan in an app. Some suggested to send a notification to them when their patients’ symptoms were increasing (the amber zone of the action plan), but a member of the administrative staff was concerned about who would pick up the alarm. In contrast, a GP thought it should be the patient’s responsibility to contact the healthcare professionals when their symptoms were getting worse.

“So I suppose that way if there was some way that linked with that then that would probably work better. So if things weren’t good then Google would tell us and then we could text back or send a message saying this is going on could you come and see us.” [Asthma nurse 01]

“It depends where the alarm is situated. Will it come up on one computer which may be through the admin area, the back area of the office? It would be annoying if it was on the actual front reception desk where we’re very busy, patients coming in, telephone calls coming, whereas if it was in a specific, you know obviously we have the admin team, you know in the rear office therefore it would pull attention and somebody would obviously attend to it.” [Administration staff 04]

“I would have thought is it not the patient’s responsibility? Because they’ll have their management plan so mostly patients will contact us if they need to. Otherwise we will have to be phoning all these people and then maybe we can’t get them so I think it would be better if there’s a trigger on this to tell them to contact someone I think that would be better.” [GP 04]

**PRISMS taxonomy components: D) Regular clinical review**

- Feature on the app prototype: N/A

The ‘wanted’ features from participants were regular review reminders and the ability to transfer log data to the practice electronic health record, facilitating the option of a teleconsultation and potentially using logged data to determine if a consultation is necessary (as opposed to arranging regularly reviews as a matter of routine).

a) Regular review reminder: most patients were positive to this feature, though the professionals’ perception of the effectiveness of this feature varied.

“Any sort of reminder does work. We’ve run trials of different reminder systems and they do work but it’s getting one that’s easy to integrate. But if you were wanting them to come in for an appointment they’d have the app and bing, remember, please attend or please phone now to change. Yes that would be very positive.” [Administration staff 03]
“We send them an invitation(text) to come in for their annual review and then they get one reminder but obviously it’s up to them if they come for that. Not everybody I guess will be seen every year.” [GP 03]

b) Log data transfer to practice electronic health record. Some patients suggested using the logs to determine if a consultation was necessary. In an interview, an experienced asthma patient in an interview suggested that logs could be sent to the healthcare professionals to review their condition. The healthcare professionals could decide if they still needed to have an annual review. If it was unnecessary, this could free up healthcare professionals’ appointment times.

“you know travelling to other countries or just getting checked up and stuff and it’s always 10 days to two weeks before you can see a nurse, whereas if you had virtual doctor online, you know or some sort of algorithm set in place where you record the information and then, you know like an Excel spreadsheet just the most important charts or something is given to the doctor he can see how many times you’ve used your inhalers or what time of the day, what you’ve eaten and stuff like that yeah that would be good.” [Patient participant A15, 26-45, M]

Non-attendance at regular reviews (especially by the working, well controlled, but also at-risk patients) was perceived as a problem by the majority of the professionals who were interviewed. Some GPs and asthma nurses suggested the app could provide another option for patients which saved patients’ time if a routine clinic consultation was not necessary and which could save healthcare professionals’ time as well as being convenient for patients. However, one GP also pointed out that generally they wanted to check the patient’s status and listen to their chest.

“I’ve wanted to do telephone consults for a long time but QOF wouldn’t really, there wasn’t any way round it because there were certain things you had to tick to say that you’d done and I think a lot of patients would pick up on that far better. Because there’s no need for them to come technically you could manage it within the realms of technology or on the telephone.” [Asthma nurse 01]

“Yes so the nurse can see them actually doing it I think would be useful. It might cut down again in the long run the time taken in the practice so if the nurse can click on and say I can see that you’re using that fine we don’t need to go through that in the appointment it may actually save time in the future or actually save having to get the patient in quite so much for doing these kind of things.” [GP 01]
**PRISMS taxonomy components: E) Monitoring of condition with feedback**

- Feature on the app prototype: use the 10 question monitoring ‘motif’ logs (symptoms, peak flow, and medication use etc) which asked patient to look at the advice in the action plan (though did not provide ‘alerts’).

Over 90% of the patients who completed the initial questionnaire said they would like to see feedback from the logs on their app. However, in reality most of the 111 users were non adherent to logging data in their 3 months usage (despite log reminders more than half stopped logging within 30 days). Of the patients who were interviewed, most felt they had well controlled asthma and that they ‘knew themselves’, therefore, it was boring or unnecessary to monitor their peak flow or their symptoms. Some patients suggested that to be useful the logging data ‘needed’ to be sent to healthcare professionals for monitoring. In contrast, one person mentioned that that healthcare monitoring by healthcare professionals was not ‘helpful’ because the patients themselves could see whether their asthma was controlled.

One GP commented healthcare professionals monitoring of logged data “was not a good way” for well controlled patients because it created dependence. Also “it goes back to paternalistic medicine and it goes completely away from the self-management”. However, it was helpful for asymptomatic patients because “they (the practices) don’t have a mechanism for knowing when people are either symptomatic or asymptomatic unless they have an exacerbation”. For logging frequency, some GPs suggested it could be adjusted for patients with different asthma controlled status.

**PRISMS taxonomy components: F) Practical support with adherence**

- Feature on the app prototype: medication reminder

The ‘wanted’ features from participants were a) medication reminder and b) low medication reminder.

  a) Medication reminder: the majority of patients were positive about this feature. Of the interviewed patients, the majority did not use this feature because they thought taking medication was part of their daily routine which they wouldn’t
forget. A few patients did use this feature because they were always forgetting to take medication. No practice’s staff mentioned about this feature.

b) Low medication reminder: the majority of patients were positive about this feature. Of the interviewed patients, those who did not have a metered inhaler or who were thinking about the rush to get the medication when it had been running out, felt this would help to “get over his/her problem”, “massively help” and “important”. No practice’s staff mentioned about this feature.

PRISMS taxonomy components: G) Provision of equipment

- Equipment provided with app prototype: N/A

Of the interviewed patients, one patient was positive about having a smart gadget to put on top of their inhaler to count the medication usage which would solve the problem they had of knowing when their inhaler was empty. No professional mentioned this in the interview.

Most of the patients had been given a peak flow meter at home, however, ownership of a peak flow meter did not encourage them to use it when their asthma was getting worse. They either lost the meter or put it aside when their asthma was stable, only using it if their asthma nurse asked them to keep a peak flow diary. No professional mentioned peak flows in their interview.

“(Not using it to log peak flow) It’s just because nobody has ever said to me, apart from the asthma nurse they do it every time I go in and I just thought it was something that she did and I didn’t need to do it every day. But I’ve got one. See that there that’s it...I would use it (peak flow meter) if I was particularly asked to keep a diary of all the, of every day what happens when you get up in the morning and I would do it(measure peak flow) then.” [Patient participant A2, 46-65, F]
PRISMS taxonomy components: H) Provision of easy access to advice or support when needed

- Feature on the app prototype: N/A

Facility for a) repeat prescription ordering, b) prescription ordering auto-checking to advise patients on overuse, and c) a ‘panic button’ for emergencies were the additional features that participants mentioned.

a) Repeat prescription ordering (either as embedded feature on app or a link to the practice website): The majority of patients were positive about this feature. Of the interviewed patients, one said it would be “useful” if this worked for other medications as well. Another patient emphasised that it was important to connect the practice’s prescription system with the pharmacy to order and collect the medication directly (which it is now standard with the EPS system. see section 1.8.3).

“It would only be useful if it would work for all the medication that I take. Because if I’ve got to go up to the computer to order in advance anyway if I can only order certain things on the app then I would have to go to the computer to order the other ones so I may as well do the whole lot in one go.” [Patient participant A4, 65+, F]

“Usually I have to get the medication regularly so I have to get a prescription and things so maybe that kind of information could be also here(on the app) that you need to probably get a new medication, you know at a certain point in time. And another option is to actually order medication so you order through this app and it would be sent to the GP straight away so the GP writes a prescription so I just go and collect it when it’s ready.” [Patient participant A8, 46-65, F]

Practices, who were using electronic prescribing (albeit not within the app prototype), felt it was “useful” and “easier”.

“we use technology for the repeat prescriptions as it is and that does reduce time which is useful” [Administration 01]

“No (I didn’t experience difficulties when using the system) I think the people that use it like it and I think it’s easier as well rather than having to empty the post box every day” [Asthma nurse 05]
b) Prescription ordering auto-checking to advise patients on overuse: One patient was surprised that his/her surgery didn’t pick up that they were over-ordering their inhalers sometimes.

“Because it’s things like sometimes I’ve maybe over ordered the Salbutamol blue inhaler without realising, I kind of forget to check what I’ve already got and keep ordering and it surprises me that the surgery hasn’t picked up and gone ‘she’s ordered a lot of those inhalers compared to what she normally uses’” [Patient participant A10, 26-45, F]

The majority of the practices already had systems (computer programmes or manual checks from time to time or annually) to check for usual dose ordering. However, it was not a real-time system to respond to patients if they were over-ordering online. An asthma nurse argued that it was ‘very, very difficult’ not to give a patient medication because this was “dangerous”. GP consultations or asthma nurse annual reviews were the time that they would pick this up with patients; however, they also recognised that not all patients would attend a GP review or their annual review.

c) Panic button for emergencies: more than half of the patients were positive regarding this feature. Of the interviewed patients, some patients suggested the panic button needed to be available even on the locked screen. Also, it would be “quite handy” if it could pop up in their medical record at the same time when the button was pressed. However, this feature had to be advertised widely so professionals (potentially around the world) would look at the phone if they attended an unconscious patient. Another patient mentioned it would be “beneficial if the medical record was in different languages”, therefore, the app can be used when they were in different countries. Patients also suggested the panic button could be connected to the duty doctor in the practice, to NHS111 or 999.
PRISMS taxonomy components: I) Training/rehearsal to communicate with healthcare professionals

- Feature on the app prototype: ability to show logs to GP/asthma nurse on app or screen capture, or to share logs with GP/asthma nurse

The majority of patients ‘wanted’ to share data with their GP/asthma nurse; the interviewed patients felt it was “useful”, “very useful” and “really handy”. It helped them to explain “a bit more in detail” to their asthma nurses or GPs; also they thought this feature would be able to help their GPs/asthma nurses to pinpoint whether their symptoms were due to asthma or some other disease.

“A combination of the two (going to talk with asthma nurse and the app prototype) I think would be very useful. Because she would be able to pinpoint days where I say that I wasn’t feeling so good and my breathing wasn’t very good or walking or on housework or something like that and she would be able pinpoint what was asthma and what was just arthritic pain.” [Patient participant A2, 46-65, F]

The majority of the GPs and asthma nurses felt it was “helpful”, “useful” and “good” to review the patient’s condition over time. However, they also felt that the data should be transferred from the app to their practice electronic healthcare records, so that they had the most up-to-date records from the patients.

“I guess it might be helpful if it could be uploaded into their notes. It might be useful as well if they go up to A&E to have information about what their asthma control has been.”[GP 04]

However, one GP further pointed out the logs were needed to be presented and used in an efficient way, as opposed to sending them a “cloud of data”. An example of efficient use of data was to use the logging data to trigger alerts at the threshold in the asthma action plan indicating follow up actions for patients and (if necessary) for practices.

PRISMS taxonomy components: J) Training/rehearsal for everyday activities

- Feature on the app prototype: logs in the 10 question monitoring ‘motif’ can be cross referenced on a single graph.

Over 90% of the patient participants wanted to see a cross-reference feature on the app. The majority of patients whose asthma was triggered by pollen or weather,
wanted to see a pollen count or weather information on the app. They suggested it would be “fascinating”, and “useful” if there was a feature that cross-referenced their asthma log with the pollen count, weather and their daily activities, and then to be able to predict their condition and highlight the risk of an attack. They also suggested it would be helpful to know how other patients in the locality were doing so they could understand the trend of exacerbations in the area. Such data would allow them decide their everyday activities; for example, to avoid an area that might trigger their asthma.

“That’s (cross reference his/her asthma with environmental factor and daily activities to predict the asthma conditions) fascinating. I would love to be part of that because it’s out with my thinking.” [Patient participant A4, 65+, F]

“So what’s useful to me is what extra information the app gives me and if it’s able to go into pollen counts and whatever and add that to my information and tell me something new that’s useful” [Patient participant A1, 46-65, M]

No professionals mentioned this option.

PRISMS taxonomy components: K) Training for practical self-management activities

- Feature on the app prototype: N/A
  - Game element: the majority of patients preferred not to include game elements (such as avatars or virtual pets or simple shooting games, designed to encourage some self-management tasks such as logging peak flow and taking medication) in the asthma app. However, some interviewed patients suggested if the game included some intelligent interaction with the app, such as an avatar to ‘chat’ with them about their asthma conditions, they would be interested as long as the speech recognition worked. Some patients were positive about a point-earning system to encourage data logging.

“I would say that would be really good but that would depend on how good they are because, you know when you try to speak to Siri and they don’t really understand you, they don’t always pick up so that could work really well but if I started doing it I would get really angry, do you know if it wasn’t recognising what I was saying then I would probably stop.” [Patient participant A5, 26-45, F]
“if there was a reward at the end of it, if there was something related to fitness or health then yeah of course it would encourage you to use something more because you’re getting something out of it it’s not just for your own benefit you’re going to get something free because everyone loves a freebie. So yeah if there was some sort of pay off then I would probably, it would remind me and encourage me to use it more.” [Patient participant A10, 26-45, F].

In the interviews, no professionals mentioned the option of ‘games’ being included in the app.

b) Checking inhaler technique: no patients mentioned checking/information about inhaler technique. A GP suggested having features that could check patient’s inhaler technique, and which could support patients to use the inhaler correctly. Checking inhaler technique was a perceived limitation of teleconsultations so overcoming this with technology could reduce the need for patients to attend an ‘in person’ consultation.

PRISMS taxonomy components: L) Training/ rehearsal for psychological strategies

- Feature on the app prototype: N/A

The app prototype did not intend to address the psychological support features, however, the diary (free-text diary with photo) and the log reminder on the app had unexpectedly provided this support to at least one participant.

a) Diary: of the interviewed patients, almost half of them didn’t use the diary. One thought logging diary helped on raising his/her spirits when feeling down. No practices mentioned this issue.

b) Logs reminder: of the interviewed patients, one thought this was ‘quite good’ – it was like someone came to him/her to support his/her asthma. No practice’s staff mentioned this option.

Incorporating stress-relieving exercise/ music elements on an asthma app was not wanted by the patient participants; fewer than half (48%) were positive to this feature. Of the interviewed patients, one mentioned it was a “good idea” if there could be a direct link on their music app interface to the ‘pop up’ asthma log
interface. However, most patients preferred not to have cross-platform links in an asthma app. No professionals mentioned the issues patients’ stress reduction or psychological coping strategies.

**PRISMS taxonomy components: M) Social support**

- Feature on the app prototype: N/A

Participants’ opinions on the potential feature of interacting via a social media page, organised by their medical practice or sharing their diary/asthma story/status via social media varied.

a) Interacting with patients via a social media page organised by their practice: no patients suggested this. One practice had a Facebook page to interact with patients, the GP pointed out that time was the “massive barrier” to running this service. Their asthma nurse mentioned that they preferred to see the patient in person, as opposed to talking with them over a computer about their symptoms.

b) Sharing diary/asthma stories/status in social media: of the interviewed patients, some mentioned that asthma was personal; therefore, they wouldn’t want to let anyone know about it on social media. One patient suggested having a social forum on the app to share asthma information with others.

“Maybe Asthma UK and that kind of organisation, maybe they could create a community for the asthma sufferers through this app, kind of like a community space, you know really useful tips or information to share.”

[Patient participant A8, 46-65, M]

No professionals mentioned social support.

**PRISMS taxonomy components: N) Lifestyle advice and support**

- Feature on the app prototype: task reminder which reminds participants of the different activities that they had set

Only two patient participants use ‘task reminder’ to remind them about their activities. Of the interviewed patients, no one explicitly talked about the task reminder.
Patient participants tended to want to incorporate exercise coaching elements/activity tracking on the asthma app. However, they were less interested about incorporating weight loss features and or smoking cessation elements on an asthma app.

a) Exercise coaching elements/activity tracking: more than half of the patient participants (68%) felt positive regarding this feature. The interviewed patients (those who had exercise induced asthma), felt it would be “quite good” “quite useful” “interesting” to be able to track their exercise level, activity related to their asthma condition (such as the numbers of inhalers they took before/after exercising). Patients who were using an exercise coaching app with an activity tracking gadget, thought it would be “easier” to watch their exercise level and asthma on a single app. However, one patient mentioned that this if this made the app more complicated it might discourage some users from using the app. No professionals mentioned this feature.

b) Weight loss feature: less than half of the patients (45%) were positive about this feature. Of the interviewed patients, those who were watching their weight, thought this was “a really good thing” and that they “would definitely keep using” the asthma app if it had incorporated weight loss or healthy eating features. No professionals mentioned this feature.

c) Smoking cessation feature: less than 5% of patients were positive about this feature. For patients who were non-smokers (66% of the 98 participants who filled in the questionnaire), the option was not applicable. Of the interviewed patients, a patient who smoked didn’t feel there was a need for it to be included in an asthma app as smoking was a personal choice. If they wanted to quit, they could get support from their local pharmacist, or other available support. No professionals mentioned this feature.
9.6 To explore the technological barriers and facilitators to using an app for supporting self-management in clinical practices (objective 3)

Patients downloaded our apps by themselves after they have received our activation code. Most of them downloaded the app, filled in the questionnaires and used the app successfully. A few participants felt it was complicated when they first started using the 10 question monitoring ‘motif’: they didn’t know how to save those questions at once. Some assistance was required for a few older adults in the download process. The assistance included: a) freeing up the memory spaces in mobile for the app, b) finding the app for iPad users as it was not placed on the Apple app store ‘iPad’ section, c) demonstrating use of the segment flower to enter and save data, and d) setting up the reminder alarm and rotating the screen to enlarge the healthcare graph.

The general suggestions on our app were

a) Explanation and presentation on app: provide more explanation on the 10-question monitoring motif and the answers, a note on the segment interface to say they can complete and save their answer in one go, provide explanations on the healthcare report graphs, enlarge the words in the healthcare report graph, provide in line presentation between the segment flower and the healthcare report graphs (high score for worse symptoms or better symptoms), plot the actual peak flow values on the healthcare graph;

b) Customisation and easy setting: allow customised setting on the 10 question monitoring ‘motif’ (allow ‘disable’ for questions which were not applicable to them); easier access to the reminder setting;

c) Share data with practice staff and patients’ relatives: link the activity tracking data to the app, share the action plan with their relatives, connect with the practice’s database and transfer their logs to the practice, provide alarms to practices if their symptoms were getting worse;

d) Implement pollen count and pollution level warnings on the home interface:

Some of the professionals suggested an app was the trend nowadays and the “future of medicine”; to have an app to support patients’ self-management was an up-to-date approach to providing better support for patients. However, most of their practices did not offer free Wi-Fi access or the Wi-Fi that they offered was unstable. This meant that they could not review the logs with the patients on.
their smart phone app during a consultation if the app’s data was cloud-based. The majority of the healthcare professionals were therefore hoping that they could be able to see patients’ logs on their practice’s electronic health records. For the app to transfer the logged data directly into the practice system, required interoperability to the different platforms that practices were using. In addition, one healthcare professional was worried the app did not support multi languages because their practice had patients who spoke different languages.

Practices also shared some of their past experience of using technology in their practices. All of them had online prescription systems. In addition, one practice was using a digital reception system to direct patients to waiting rooms. Another practice had used an online booking system in the past, however, they were uninstalling this feature because patients were more often failed to attend timeslots they selected online compared to the usual telephone-based appointment system. They suggested this wasted GPs’ time and was not effective and decided to stop using it. All of the practices were using an online prescription system which was valued by the patients, though one person raised concerns about whether there was a feature to automatically check for over ordering of prescriptions. Professionals advised that a warning popped up on the practice’s computer screen if there were an unusual number of prescriptions ordering. In the Lothian practices, checking on unusual prescription ordering was done by the Scottish Therapeutics Utility (STU). In other practices, a similar module was supplied by their platform provider. In addition, some of the practices had a staff member who manually checked any unusual ordering.
9.7 To explore the legislative barriers to developing an app to support asthmas self-management (objective 4)

9.7.1 What do patients think of the risks from an asthma app?

With the experience of the risk-averse approach to protecting patient’s safety of the legislative directive, I wanted to explore what patients think about the risks that an asthma app (incorporating an action plan) would bring to them. Therefore, I invited the stream A patients to discuss their thoughts on the potential risks associated with an asthma self-management app. This exercise aimed to get a feel of the risks from the patients’ perspectives and to help shape the future development of apps.

In general, the patients suggested that data privacy was the main risk. They were not worried about getting wrong advice from the app because they were adults and could decide whether the advice was making sense to them. The app was just a tool to assist their decision-making but they would not entirely rely on it. Some patients further explained that maybe the professionals who design telehealth, should trust them, the end users, more and understand better how they use an asthma app. Although this finding was not held by all the asthma patients, it suggested that further research was needed to understand how patients interact with an asthma app before reaching conclusions on aspects of apps that should be subject to regulation. Below are some of the opinions expressed.

“I don’t see how your app is dangerous unless there are other problems with the patient...Well if you can’t trust a patient to put the right information in like two puffs in the morning how can you trust the patient to actually do the two puffs in the morning? If a patient is capable of saying ‘Oh yes, Morning. I’ve got to get my inhaler out’ If they’re capable of doing that they’re surely capable of putting a number two in for an app.”[Patient participant, 65+]

“I don’t think it has a risk for me. Yeah. And I wouldn’t take what the app said as gospel. So every time I fill out your motif it tells me that I should book an appointment with my doctor because my asthma is not managed, however I was at the clinic not that long ago and it was fine so I think it edges on the side of over cautious I don’t think there’s a risk that I would end up bad.”[Patient participant, 26-45]
Chapter 10 (Phase 3) Discussion

In this chapter, I will first describe the main findings from the feasibility study, and discuss the limitations and strengths of this study. Then I will compare my results with findings in the previous publications. In chapter 11, I will discuss the findings’ implications and suggest future directions regarding using an app to support asthma self-management.

10.1 Summary of findings

We provided a app prototype, incorporating an asthma action plan, to support asthma self-management. 111 adults, aged 16+ years old, with ‘active’ asthma, adopted the app for three months. 15 patient participants, 16 healthcare professionals including asthma nurses, GPs, administration managers and a receptionist in Lothian/Oxford were interviewed. The ownership of an action plan increased from 43% before the study begin to 63% after the study. Most of the patient participants suggested the app prototype had raised their awareness of asthma and, in particular, when they need to seek help from their GP or asthma nurse.

Clinical perspective: (Objective 1a and 1b). 1a) to test the feasibility of the using the self-management support features in the app prototype and 1b) to identify features that patients and professionals would like added/excluded mapped to the taxonomy

Provision of asthma action plans, monitoring of patients’ conditions with feedback and providing training/ rehearsal for their asthma activities comprised the self-management support that both patients and professionals would like to see on an app. Few patients wanted game elements to support their adherence to self-management or medication. Patient participants wanted to see lifestyle advice and support on the app, especially exercise coaching elements and activity tracking, as opposed to advice relating to weight loss and smoking cessation support. The application features that they would like to see on the app are illustrated in Figure 41.
Figure 41 Schematic of the features that patients and healthcare professionals wanted to see in telehealth
Numbers 1-9 show the nine application features that were identified. The data flow, input and output were showed on the schematic.

1. Feature 1 is the data logging system, preferably customisable, so that the user can enable or disable the logs that they want.
2. Feature 2 is the system to help users learn the correct peak flow and inhaler technique (for example, image recognition on incorrect peak flow posture).
3. Feature 3 is a simple weather information display system.
4. Feature 4 is an alarm system for geographical areas currently experiencing frequent asthma exacerbations.
5. Feature 5 is the digitised asthma action plan system. The action plan could be the Asthma UK action plan or a series of actions agreed between the GP and the patients. Also there is a feature to correlate patient logs, and weather with their asthma status; unusual patterns could be sent to the GP for further advice.
6. Feature 6 is the medication reminder for patients who want to use it.
7. Feature 7 is a consultation appointment booking system.
8. Feature 8 is the repeat prescription ordering system.
9. Feature 9 is the emergency system.
**Patient perspective: (Objective 2a). To compare the attractiveness of the app prototype to patients recruited via their practices or social media**

The number of downloads from social media far exceeded those from practice recruitment, though the proportion of people recruited after a personal approach by the asthma nurse was greater than that from the social media. The higher ‘hit rate’ from personal approach invitations suggested that, in the long run (for example 2-3 years), a practice that persistently invited people to use an app could be very effective. This view echoes the finding that most of the patient participants suggested they would download an asthma app to support their self-management if it was recommended by people they knew and trusted.

**Patient perspective: (Objective 2b) to explore the adoptive and adherent features that influence patient engagement with asthma self-management**

In the context of the study, in-person encouragement such as a personal invitation from their GP or nurse, or an interview with me for research purposes, provided the trigger and motivation for patients to download an app to support their asthma self-management. Other motivations were perceived health benefits such as improved asthma control, and curiosity about the technology. Good asthma control and not owning a smartphone reduced motivation to download.

The usage rate of the app decreased over time. Most of the large number of patients recruited from social media stopped using the app within 30 days; in contrast, patients recruited by their practices were inclined to use the app for longer. Pop up notifications to remind patients to go back to the app prototype were only effective for the patients who were motivated to use it. The key motivations to continue using the app were the in-person encouragement from the GP or asthma nurse, or in the context of the study, being interviewed by me for research purposes. Others motivations were the perceived health benefits such as being more aware of their asthma, and practical advantages such as preventing loss of their paper asthma action plan and the opportunity to carry out efficient logging of their asthma symptoms.
Technology perspective: (Objective 3) To explore the technological barriers and facilitators to using an app for supporting self-management in clinical practices

Some technical assistance was required from older patient participants in the download process. The principal technical barrier for professionals was their inability to easily access the logged data, either because they did not provide seamless Wi-Fi in their practice, or because app data could not be transferred with the practices’ electronic health records. Other barriers included lack of time and resources to explain the app to patients and respond to their technical problems in practices. A third party able to deal with routine technical problems and answer patients’ enquiries on the system would be helpful to overcome these barriers.

Legislative perspective: (Objective 4). To explore the legislative barriers to developing an app to support asthmas self-management

Current legislation may have over-interpreted the actual risks of an asthma self-management app. Patients are the end users of the self-management app; therefore their opinions on the risks to them of using the app should be considered when developing the legislation. Further research is needed to a) understand how patients use an app to support their asthma self-management and b) to identify any actual risks involved, to order to inform future legislative work on asthma self-management apps.
10.2 Limitations of the three months feasibility study

- **Design**: There were three main recruitment channels in this study, but the practice invitation letter, in-person consultation and social media modes were not mutually exclusive. They interacted with each other, such that patients may have received our recruitment information from more than one of the channels. For example, patients may receive the invitation letter by the practice and also read our advertisements on the social media. Therefore, the adoption rate from one channel may be the result of receiving information from a combination of two or three channels. However, in the initial questionnaires and interviews I asked the patient participants who had heard about our app to identify the channel(s) from which they received our information. I also asked asthma nurses for the patients’ responses to their invitation. I identified there were a few patients had received our information both from the invitation letter and consultation.

- **Generalisability**: Several factors limit the generalisability of our findings. The patients and practice participants were people who were interested in the issue of telehealth:
  a) Firstly, the patients were mainly from the Asthma UK or AUKCAR Facebook or Twitter, or via retweets by those centres’ followers. The patient participants were therefore a group of people who were interested in knowing more about asthma and/or interested in technology. We aimed to purposively sample for the qualitative study according to age, action plan ownership, technology experience and therefore recruited participants in each of these categories. However, the sample had an over-representation of people from the ‘working’ and ‘older age’ groups, who were without any experience of any healthcare apps.
  b) Secondly, having a smartphone or tablet was a requirement for our participants; therefore, people without smartphones or tablets were excluded, though the ‘lack of ownership’ variable is becoming less of a problem year by year (smartphone penetration rate in the UK increased from 62% in 2014 to 85% in 2017)[224]. Furthermore, our patient participants may not
represent all the adult asthma patients in the practices because we had excluded those with high risk asthma, though these are a small minority.

c) Thirdly, our practice participants were from the Lothian area and Oxford, reducing the generalisability of our findings to other countries where game elements, especially those with the famous cartoon characters such as Tamagotchi[225], could be one of the most attractive features of the app.

d) Fourthly, the practice recruitment started at different times of the year in some practices, encompassing the Christmas holiday which may have affected the adoption rate. The different starting times were because the cross boundary HRA applications and the practice recruitments took longer than we expected. Lastly, a number of our participants said that ‘helping research’ was one of the motivations for participation, which would not apply to a normal patient population outside the research context.

- **Duplicate coding:** Budget and time restrictions precluded the employment of a second researcher to code the qualitative data and undertake duplicate analysis. However, I discussed the coding with my supervisory team and discussed the early results in the conferences in order to aid a balanced interpretation of the data.

- **Duration of the study:** The short duration (3 months) of the study limited the number of participants recruited by the nurses and underestimated the ultimate impact from the practice nurses’ in-person invitations. Nurses often only saw patients annually, so only a minority of patients will have had annual reviews in the study period. Also practices did not change their routines to account for the new way of working (e.g. by increasing provision of remote consultations) so that some of the app’s potential benefits may not have been apparent. Some patients suggested they would like to make logs for longer and review the data with their practices in their annual review. However, we could not follow up their usage pattern because our study had closed before their reviews.

- **Lack of data access.** I was unable to extract the detailed usage data of each feature on the app prototype, such as i) the average time participants spent on each module, ii) the number of times that participants returned to the app after the notifications and iii) the numbers of times that participants had looked at the action plan on the app, were not available. I was only able to measure their log
time and frequency on the module, which limited further understanding on how participants interacted with each of the features. However, in the final questionnaire, the patients were asked about their usage of different features to supplement the information.

- **The app’s interface.** As the app prototype was limited to the standard configurations set by the technology company, there was only limited flexibility to change the module and design (button, notification, message box and positions). This limited the features that were provided, which may have influenced opinions. However, we explored other features with patients in the interviews and initial online questionnaire.

- **The responses.** Participants’ responses to the online questionnaires only provided limited insights into what they would like to see on an asthma app, though I was able to explore findings in the qualitative interviews. In addition it was possible to include some free-text comments from the questionnaires and feedback on social forums received from a wider population.

### 10.3 Main strength of the three months feasibility study

This study gave a novel insight into the features of mobile applications which were utilised and associated with attractiveness and adherence from the patients’ and practices’ perspectives. The app prototype was developed based on the framework for developing and evaluating complex interventions[55] but also catered for the required rapid app development cycle as happens in the real world. The study thus bridged the gap between clinical and technical developments on telehealth. The findings provided evidence to inform future asthma management app design.

- **Sample size:** overall, 111 patient participants were recruited, which reached the sample size we estimated in order to assess the fall-off in use of the app at 30 days with 80% power with 95% confidence interval to detect a difference with a maximum half-width of 10%. However, we did not have the power to detect differences between the study streams, as the majority of the participants were in stream C.

- **Consistent comments:** questionnaire responses from stream C patients shared the same thoughts with the interview findings from stream A participants. This
outcome increases confidence in the validity of the findings and allows the questionnaire responses to be explored.

- **Training and support:** I provided standardised training to the nurses before recruitment. A comprehensive recruitment pack was provided, which included a ‘3-minute recruitment’ guide for nurses to use; contents: i) aim of our study, ii) invitation process, iii) sample invitation script and iv) our enquiry email and telephone. The nurses did not have to teach the patient how to download or use the app; a tutorial and enquiry message box were available on the app and all technical enquiries were sent to me or our software partner.

- **Design:** the feasibility study provided a wider sense on users’ adoption and adherence, and also helped to identify the key issues before assessing the effectiveness of the app prototype. Most importantly, it fitted into the app’s rapid development cycle by i) allowing me to identify factors that affecting the app design; ii) allowing me to understand how users would interact with the app in just a few months.

- **Mixed methods approach:** this enabled me to synthesise quantitative and qualitative aspects, so the survey provided an assessment of the weight of opinion, and the qualitative study could provide a depth of understanding.

- **Broad entry requirement:** We used broad eligibility criteria to include almost all patients with ‘active’ asthma, thus aiming to reflect the typical asthma population in participating practices. There was no upper limit to the age, no limit on whether their asthma was controlled or uncontrolled (apart from excluding the very few patients under the care of ‘difficult asthma’ clinics), no requirement to have used an action plan previously, or to have experience with healthcare apps.

- **One stop eligibility checking, consenting and online questionnaires on app:** to reduce the complexity of checking eligibility, consenting and sending questionnaires back and forth using reply-paid envelopes and emails, we implemented the processes on the app. Before participants could start using our app, the app checked their eligibility, obtained their consent for using their demographic and app usage data in this study, and invited them to fill in the initial questionnaire. After they had used the apps for 90 days, they were prompted to fill in the post-study questionnaire on the app. This approach
simplified the process for patient participants to register with our study and was in keeping with the nature of an ‘app’ based study.

- **Broad approach to collecting views**: As advised by our lay advisory group, in order to explore a broader view from our participants, I explained clearly in the initial interviews that our study was not specifically about refining our app’s prototype to be launched in the market, and then further emphasised that we would like to hear both good and bad feedback in the study. This was helpful to relieve participants’ worries about giving their negative feedback. I had indeed received a few emails from patients who had worried that their negative feedbacks or irregular usage would affect our study or possibility to launch our app in the future. After explaining to them, those concerned correspondents eventually became our participants and their thoughts were included in our study.

- **Interpretation of findings by multi-disciplinary groups, the PPI and lay advisory groups**: the emerging findings were presented at the European Respiratory Society Congress and Primary Care Respiratory Society annual conference, and discussed with my supervisors, colleagues from the Asthma UK Centre for Applied Research, and the patient and public involvement group. Those discussions allowed me to obtain a wider perspective on the interpretation and implications of the findings.

- **Reporting**: I used the GRAMMS reporting standard, as recommended by the EQUATOR network for reporting mixed method studies in sufficient detail to enable a reader to reproduce the study[184]. This ensures rigorous and transparent information for a reader to assess the quality of the study.

### 10.4 Critical assessment of the qualitative study

Critical assessment is “the process of systematically examining research evidence to assess the validity and relevance of the results before using them to inform a decision”[226]. Amongst many assessments tools, the critical appraisals skills programme (CASP)[227] includes a tool that provides a checklist to assess the quality of a qualitative study. The checklist is a self-reflection form, with 10 questions and answers of “yes”, “no”, “can’t tell”, to help researchers to think about their study design. I adopted this checklist to assess my study because it provides a
systematic way to assess qualitative research in ten clear questions. Below is the CASP assessment for my qualitative study (see Appendix 23) for the checklist.

- **Was there a clear statement of the aims of the research?** The aim of the qualitative study was to identify the adoptive and adherent features that influence patient engagement with asthma self-management. This is clearly stated in section 8.1.3. It formed an important component of the mixed methods study because it supplemented and provided perspectives on the quantitative data in the study.

- **Is a qualitative methodology appropriate?** The methodology was appropriate because interviews enabled me to seek individual participants’ feedback in depth and provided a more comprehensive understanding of what patients wanted in an asthma app.

- **Was the research design appropriate to address the aims of the research?** Building on previous work (chapter 3: systematic review), the qualitative study aimed to explore the adoptive and adherent features identified in the quantitative questionnaires. The pre-post study design enabled me to explore adoptive features shortly after the patient had decided to download the app, and adherent features after a month’s use of the app. Interviews enabled individual feedback on the experience of using the app, and framework analysis was appropriate to answer the aims and objectives of this study. The design justification is explained in section 7.4 in detail.

- **Was the recruitment strategy appropriate to the aims of the research?** The participants were adults with asthma because I wanted to explore an app designed to support self-management; children would be expected to have parent/carer caring for their asthma. I purposively selected a range of age, gender and experience of using healthcare apps because the dynamic of app use and self-management strategies are likely to be different in participants in these different groups. A poor response rate to the invitation letter and over-representation of women limits generalisability. By using three different recruitment approaches in the quantitative study, I was able to identify differences in adoption and adherence according to the initial approach. Details are reported in section 7.4.2.
- **Were the data collected in a way that addressed the research issue?** The data were collected by individual interview because I wanted to explore the patients’ opinions in depth without being influenced by other interviewee’s thoughts (see section 7.4.1). The topic guide was informed by my previous systematic review (chapter 3: systematic review) with the advice of the lay and professional advisory groups and was revised iteratively in the light of the initial interviews and quantitative findings. (see section 8.1.10). I recruited 15 participants as likely to be sufficient to provide data saturation (see section 7.4.3: Sample size).

- **Has the relationship between researcher and participants been adequately considered?** I considered my identity as a researcher, with experience in engineering, would influence my understanding of the collected data. I therefore discussed the data with multidisciplinary teams and presented in conferences to help me to maintain a balance between different understandings and points of view (see section 7.4.3: Reflexivity).

- **Have ethical issues been taken into consideration?** The study complied with ethical standards and obtained approvals from the NHS South East Scotland East Scotland REC 02 and NHS HRA. The approval documents are presented in Appendix 11 and have been reported in section 8.1.1 and 8.1.9.

- **Was the data analysis sufficiently rigorous?** The data analysis is described in section 7.4.3. All interviews were transcribed and used in the framework, though limited resources meant the coding was done by one researcher, though in discussion with a multidisciplinary team. Analysis was underpinned by the Fogg behaviour model. (see section 8.1.10). My background and the potential influence this will have had on the analysis were discussed in the section 7.4.3: Reflexivity.

- **Is there a clear statement of findings?** The study findings are explicitly related to my research objectives (see chapter 9 which reports the findings according to each research objectives). The findings are consistent and validated with the findings from quantitative methods. This is explained in the section 10.3. Discussions in related to the research questions are reported in section 10.1. and the interpretation of the findings against other published literature is reported in section 10.
• *How valuable is the research?* The research findings have implications to the healthcare policy, NHS asthma app designer and telehealth research (see chapter 11). The findings are not generalisable to other populations which are explained in section 10.2.

10.5 *Interpretation of findings in relation to previously published work*

10.5.1 Patients’ adoption and adherence behaviour mapped on Fogg behaviour model

Fogg behaviour model[195] suggests motivation, ability and trigger must come together at the same time for an action to be produced. I mapped my findings to the Fogg behaviour model[195] in order to interpret my findings. See section 7.4.1: theoretical underpinning, for an overview of this model.

*Adoption*

To download the app prototype to look after their asthma, it is either Fogg’s green dot or blue dot behaviour for patients (see section 7.4.1: theoretical underpinning)[197]. Green dot behaviour represents a one off, new behaviour; blue dot behaviour represents a one off, familiar behaviour. Download is a one off behaviour. If the patient has no experience on downloading an app, this is a new behaviour for them. Otherwise, this is a familiar behaviour.

For the patient who is downloading an app for the first time, this event is classified as green dot, one-off and new behaviour exemplified by:

a) Motivation: we need to increase the patient’s motivation to overcome lack of interest in, or concerns about, using apps by highlighting the benefits of the action;

b) Ability: we need to increase each patient’s ability by explaining the download process in terms familiar to the patient, while making no assumptions that they will understand any of the process;

c) Triggers: Fogg describes three types of triggers: i) facilitator, ii) signal and iii) spark:

i) Facilitator trigger is used for highly motivated and low ability patients;

ii) Signal trigger is used for highly motivated and high ability patients;

iii) Spark trigger is used for poorly motivated, high ability patients.
In summary: for green dot behaviour, the trigger needs to be ‘facilitative’ i.e. highly motivating and the action must seem very easy.

For the patient who is familiar with downloading an app from the app store, this event is classified as blue dot, one off and familiar behaviour exemplified by:

a) Motivation: we need to provide sufficient motivation to the patient, but the motivation may be short lived;
b) Ability: this is less of a problem as the patient knows how to download an app so has the ability to perform the behaviour when the trigger occurs;
c) Trigger: this is likely to be a ‘spark’ trigger: the patient’s ability is high but his/her motivation is low; we need to make sure the trigger prompts the patient to do the behaviour now.

The study’s findings resonated with these patterns. Patients from social media – presumed to be familiar with using apps – responded very rapidly to the trigger of tweets from Asthma UK, though the ‘hit rate’ (proportion of patients responding/registering) was lower than for the patients recruited from the practices, as their motivation levels were relatively low. Those recruited by personal invitation from the asthma nurse were highly motivated, but some were less confident about using smartphone apps. This situation is summarised in Table 29 and discussed below.
Table 29 Influence of motivation, ability and triggers on adoption mapped to Fogg behaviour model

<table>
<thead>
<tr>
<th>Fogg behaviour model</th>
<th>Recruitment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Social media</td>
</tr>
<tr>
<td>Adoption</td>
<td>Motivation</td>
</tr>
<tr>
<td></td>
<td>Ability</td>
</tr>
<tr>
<td></td>
<td>Trigger</td>
</tr>
</tbody>
</table>

Table 29 Influence of motivation, ability and triggers on adoption mapped to Fogg behaviour model

a) **Motivation:** most of the participants suggested that a personal invitation from their GP or asthma nurse was a priority motivation to encourage them to download. Motivation in the pink ‘practice recruitment’ triangle is therefore high. In contrast, motivation of those contacted by social media (blue triangle) is much less, perhaps only in the form of curiosity. Interest in research or perceived health benefits were potential motivators in both groups.

b) **Ability:** the process to download the app prototype is much easier on a social forum than the healthcare professionals’ invitations: a situation as illustrated by the positioning of the triangles on the x-axis. The patient just needs to click on the direct link in the tweet/advertisement to download the app. Patients from practices, however, had to find time (and remember) after the asthma review to use their phone or tablet, and then needed to follow the download instructions on the paper information leaflet.

c) **Trigger:** patients from healthcare professionals were triggered by their GP’s invitation letter or asthma to download the app prototype; whereas patients from social media were triggered by the advertisements on Asthma UK and AUKCAR’s Facebook and Twitter. The invitation from their practice is more personalised for the patients; advertisements on social media are more impersonal and casual for the patients. Both of these triggers were able to
prompt patients to think of downloading the app prototype – but the personal invitation was the stronger of the two.

Therefore, my findings resonate with Fogg behaviour model[195]. From his behaviour grid[197], I identified that ease of access to download is the key to adoption. The process needs to be assisted with sufficient motivation, preferably in the form of prioritised motivation from a GP or asthma nurse invitation. Both practice invitations and social media contacts can be the trigger to prompt downloads. Apart from putting direct links on social media, there are numbers of ways to provide easier access to download for patients who are motivated by a personal invitation from their asthma nurse or GP. For example, the practice could put a QR code or Near Field Communication (NFC) tag on a letter or leaflet, GP prescription counterfoil, poster in the practice, so that the patient can scan the code or use their phone to touch the tag and they will be directed to the download. The asthma nurse could send the download link to patients who want to download the app after consultation. Another possibility is to set up an auto SMS sending system in the practice; once the patient comes to the healthcare professionals, they will receive an auto SMS, with a direct link to the download, asking them if they would like to try it out.

Adherence

To continue to use the app prototype to support self-management is green path behaviour[197] (see section 7.4.1: theoretical underpinning) Green path behaviour represents the start of a new behaviour from now on; that is to start using the app prototype from now on. The steps required to support patients to continue to perform this behaviour are i) to boost their motivation, ii) make the task easier and iii) prompt or trigger at those times when the patient is motivated and has the confidence to complete the task.

From my findings it is shown patients from social media rapidly stopped using the app; in contrast people recruited via their practice were more likely to continue using the app for 30, or even 90 days.
### Fogg behaviour model

<table>
<thead>
<tr>
<th></th>
<th>Recruitment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Social media</td>
</tr>
<tr>
<td>Adherence</td>
<td>Motivation</td>
</tr>
<tr>
<td></td>
<td>Patients' motivations were low, with no encouragement from their practice and no further social media communication.</td>
</tr>
<tr>
<td>Ability</td>
<td>Patients' abilities were good as most reported few problems with using the app.</td>
</tr>
<tr>
<td>Trigger</td>
<td>Trigger in the form of notifications and reminders were available on the app.</td>
</tr>
<tr>
<td></td>
<td>Practice</td>
</tr>
<tr>
<td></td>
<td>Patients' motivations were relatively high, both because of the interest of their healthcare professional but also the group providing interviews were personally involved in talking with a researcher.</td>
</tr>
<tr>
<td></td>
<td>Patients' abilities were good as most reported few problems with using the app.</td>
</tr>
<tr>
<td></td>
<td>Triggers in the form of notifications and reminders were available on the app.</td>
</tr>
</tbody>
</table>

**Table 30 Influence of motivation, ability and triggers on adherence mapped to Fogg behaviour model**

a) **Motivation**: personal encouragement, research elements, perceived health benefits and practical benefits such as features that save time made up the positive motivations. The key difference between the patients from social media and the personally invited patients was the lack of personal encouragement throughout the usage period. The patients from practices were invited by their GP and asthma nurses, were able to arrange extra consultations with their GPs and asthma nurses for this app prototype, and were interviewed for the research before and after they had used the app for one month. In contrast, patients from social media, used the app on their own. Personal encouragement is one of the key motivations to maintain the behaviour.

b) **Ability**: All patients used the same app prototype throughout the study and once the challenge of downloading the app was overcome, the difficulty of performing the task was similar in both groups. Technical assistance was provided for all patients.

c) **Trigger**: all patients received pop up notifications to prompt them to keep using the app prototype (unless they had disabled the notification manually). This trigger was only effective in promoting action in those patients who had a good motivation but needed a reminder that the app was there to help them.
Therefore, motivation is the key to adherence. GPs’ and asthma nurses’ encouragement is a key motivator along with perception of benefit; but such motivation will be more effective if the app is easy to use. Pop up notifications are workable triggers for patients with positive motivation.

10.5.2 Utility as a support for self-management mapped to the components of the PRISMS taxonomy

Table 31 summarises the findings of all phases of my research mapped on the PRISM taxonomy. I will then discuss the features that people like/want in apps in relation to the wider literature; and consider the potential contribution of technology in section 10.4.3. The pivotal role of legislation in enabling this is highlighted in section 10.4.4.
Table 31 Summary table of PRISMS and application features

<table>
<thead>
<tr>
<th>Taxonomy item</th>
<th>What features are already offered in the telehealth interventions or apps? [SR: Systematic review; S: Social media analysis; A: App review]</th>
<th>What features do people like/ want in apps?</th>
<th>What more can technology do?</th>
</tr>
</thead>
</table>
| A. Information about asthma | Knowledge bank of asthma such as to provide links about asthma management and environmental information, for example, pollen count and temperature [SR, A] | • Self-management information  
• Environmental information on the app home page instead of a link to website to the information | • Providing real time environmental information on the app’s home page  
• Provide information such as social or peer supports, charitable organisations |
| B. Information about available resources | Not offered in the interventions or apps | | |
| C. Provision of/agreement on specific clinical action plans and/or rescue medication | • Asthma action plan with exacerbation detection to trigger notification to healthcare professionals[SR]  
• Asthma action plan [A] | ‘Intelligent’ action plan such as  
a) auto updating after consultation  
b) notify patient’s GP or asthma nurse when symptoms is getting worse and give advice | • Interoperating the app with practices’ databases to exchange real time data  
• Built in algorithm on app to trigger alert to GP or asthma nurse when patient’s symptoms are getting worse. GP or asthma nurse to decide if the patient needs a follow up in-person consultation for advice; or to provide tele consultation; or to provide online consultation |
| D. Regular clinical review | Regular clinical review by healthcare professionals[SR] | • Regular review reminder  
Log data transfer to practice health record to determine if a consultation is necessary | |
| E. Monitoring of condition with feedback | • Electronic diary to log symptoms, peak flow, ACQ for decision making [SR]  
• Logging peak flow and advice on the severity of asthma [S,A]  
• Logging dose taken for future practice’s advice[S,A]  
• Logging symptoms and advice on the severity of asthma [S,A]  
• Other logging: triggers and pollutants | People in general like to log peak flow, asthma medications and symptoms. They also like to personalise the monitoring parameters | Providing a list of monitoring parameters for patients to choose on app. The patient can disable the unnecessary parameters on the app interface |
<table>
<thead>
<tr>
<th>Taxonomy item</th>
<th>What features are already offered in the telehealth interventions or apps? [SR: Systematic review; S: Social media analysis; A: App review]</th>
<th>What features do people like/ want in apps?</th>
<th>What more can technology do?</th>
</tr>
</thead>
</table>
| F. Practical support with adherence | Medication reminder [SR, S, A] | • Medication reminder  
• Low medication reminder | Reminding patient to take medication and remind them before their medication is running out and providing a quick button to (re)order medications |
| G. Provision of equipment | Smart gadget, smart peak flow meter [SA, S, A] | Patients wanted smart gadget to count medication usage. | For inhaler: providing a reasonably priced smart gadget that can plug on the inhaler and connected to apps to count medication usage  
For other medications: pharmacy can print a QR code on the medications. Patient to scan the QR code of bar code on the medication when starting the medication. The app can then use built-in algorithm to estimate the medication usage |
| H. Provision of easy access to advice or support when needed | Emergency call button [S] | • Repeat prescription ordering (either on app or a link to the practice website)  
• Prescription ordering auto-checking to advise patients on overuse  
• Panic button for emergencies | A quick button on app’s home page to request prescription or link to the practice website  
Providing built-in algorithm to pop up warnings to patient and healthcare professionals for over-ordering of prescription  
Machine learning for patient’s daily coughing pattern; auto detection for emergency condition and call ‘999’ |
<p>| I. Training/rehearsal to communicate with healthcare professionals | Showing or sharing logs with GP or asthma nurse on app/via PDF [SR, S, A] | Showing or sharing logs with GP or asthma nurse | Interoperating the app with practices’ database; allowing patients to send their logging to GP or asthma nurse by one click on app |</p>
<table>
<thead>
<tr>
<th>Taxonomy item</th>
<th>What features are already offered in the telehealth interventions or apps? [SR: Systematic review; S: Social media analysis; A: App review]</th>
<th>What features do people like/want in apps?</th>
<th>What more can technology do?</th>
</tr>
</thead>
<tbody>
<tr>
<td>J. Training/ rehearsal for everyday activities</td>
<td>Highlighting the areas which of high risk of asthma attack on a map [S]</td>
<td>Cross referencing patient’s asthma with environmental factors and their daily activities; in order to predict their conditions and highlight risk of an attack</td>
<td>Using machine learning to learn patients’ triggers, symptoms and exacerbation patterns, cross referencing real time environmental factors and give warning of the areas which are of high risk to patients</td>
</tr>
<tr>
<td>K. Training for practical self-management activities</td>
<td>• Pop up questions to assist data logging [SR] • Personalised reminders for self-management activities such as booking appointment reminder and logging peak flow reminder. [S,A]</td>
<td>• Intelligent interactive element or point earning system to encourage data logging • Checking inhaler technique</td>
<td>• Implementing avatar or smart home gadget to interact with patients to remind them about their self-management activities; as well as partner with café and supermarket to set up point system to encourage logging • Using image recognition to check a patient’s inhaler technique</td>
</tr>
<tr>
<td>L. Training/ rehearsal for psychological strategies</td>
<td>Not offered in the interventions or apps</td>
<td>Diary and logging reminder could be a way to raise patient’s spirit and a feeling of caring</td>
<td>Stress-free exercises, music and remedies can be an add on feature on the app, that is, patients can download it directly on the app’s interface when they need</td>
</tr>
<tr>
<td>M. Social support</td>
<td>Not offered in the interventions or apps</td>
<td>Patients had a mixed wants for social supports’ features. Sharing diary/asthma story/status could be an optional features for patient to choose</td>
<td>Sharing diary/asthma story/status can be an add on feature on the app, that is, patients can download it directly on the app’s interface when they need</td>
</tr>
<tr>
<td>N. Lifestyle advice and support</td>
<td>Logging lifestyle (e.g. activity, mood, food) over asthma condition [S,A]</td>
<td>Incorporating exercise coaching element and activity tracking on the asthma app</td>
<td>Linking the app with activity tracker gadget, according to patient’s asthma conditions. Using machine learning to provide personalised exercise coaching to patients.</td>
</tr>
</tbody>
</table>
Supporting features that patients and healthcare professionals wanted to see in an app to support self-management

Patients and professionals agreed that a self-management app should support the provision of action plans and use of rescue medication, though in reality, apps rarely do this at the moment. Training/rehearsal for everyday activities, such as cross-referencing environmental factors to advice on daily activities, was also valued. The commonest existing feature, and one included in our app prototype, was monitoring of the patient’s condition with feedback. This resonates with the findings in other studies.

- **Action plan:** Odom et al.[228], reported the feedback from patients and technology providers about an app that included an action plan targeted at adolescent asthma patients. Their findings suggested that most of the teenagers agreed that the app helped to give advice when they needed it during an asthma exacerbation and that they would use it ‘frequently’. Mendiola et al.[54], explored the valuable features in general healthcare apps, as opposed to only asthma apps. The researchers found that a) providing advice for better managing of a condition and b) sharing data with healthcare professionals were the most valuable features for patients.

- **Logging:** my review work highlights that monitoring (or ‘logging’) was a feature that was provided in the most downloaded asthma apps in the market (see section 5.4.5). Other studies, a) Huckvale’s systematic assessment on asthma apps[44] suggested that logging was offered in most of the apps from 2011 to 2013; b) Mendiola et al.[54] further suggested the logging features need to be executed properly in order to attract patients to keep using the app.

- **Supporting everyday activity:** my review (chapter 4, social forum analysis) found that patients wanted to monitor indoor and outdoor pollutants, as well as mapping the pollen count on their asthma severity, in order to learn more about how their daily activities would affect their asthma. This knowledge would enable the patient to plan what to do in their routine daily lives for a better asthma outcome. This feature is a form of personalised learning to assist patients to live with day-to-day challenges. Support for patients’ learning about asthma is recommended in the BTS/SIGN guidelines[24].
Therefore, these findings suggested that these three supporting features were those that patients and practices would mostly like to see on an app, though the associated application features and the app’s interface designs may need to be refined with the end users.

*App for optimal asthma self-management*

In this study, I found that many of the patients had already developed their own strategy, or ‘plan’, for looking after their asthma; for example, taking the preventer inhaler at regular times and using the reliever inhaler before exercising. This plan was based on what they had learnt from their past experience and the suggestions from the GP and asthma nurse. This finding resonates with the preliminary results from Daines[229] in a parallel project (Implementing Improved Asthma self-management as Routine Treatment (IMP2ART) in the Asthma UK Centre for Applied Research. He also found that, for most patients, asthma self-management evolved over a lifetime or through trial and error, influenced by healthcare providers. Most had developed their own strategies and habits for looking after their day-to-day asthma, and did not always see the need to attend the regular annual asthma consultations. However, information on what to do in unexpected situations (such as attacks) was seen as helpful[230].

However, we know that “optimal self-management” almost halves the risk of unscheduled care[27] by incorporating not only action plans and self-monitoring but also discussions with healthcare professionals and undertaking regular reviews[24]. Therefore, future asthma self-management apps should contain features to strengthen the connection between patient and professional. This arrangement could work by facilitating discussion between the patient and their GP and/or asthma nurse about their routine plans, and encouraging patients to participate in regular consultations. Indeed, both patients and practices wanted to see these features in future asthma apps (see Figure 41 in section 10.1). The specific features that may support this are: a) to allow the app’s data to be transferred to the EHR in the practice’s computer, so that the GP and asthma nurse can view the most up-to-date information from patient; and b) to provide asthma action plans as well as c) personalised advice on the app. Apart from the standardised asthma action plan, for example, Asthma UK’s action plan (see Figure 1)[36], could consider providing additional space on the app to allow
GPs, asthma nurses and patients to enter further personal strategies to manage their asthma. A ‘notepad’ for patients to jot down questions they want to discuss with their asthma nurses or GP in the next routine review might be useful for some patients.

However, a crucial caveat is to prevent the overflow of unnecessary data to GP practices. Enabling GPs and asthma nurses to select parameters they wish to review with patients in the course of a consultation is likely to be more acceptable than expecting healthcare professionals to monitor the data. One of our GP participants explained why practice-monitoring is inappropriate for future asthma apps. He said this feature was ‘going back to paternalistic medicine’ and ‘went completely away from the self-management’. Another study shared the same view as this GP[231]. Although access to monitoring data may be useful to inform healthcare professionals during reviews or in consultations when a patient’s asthma is deteriorating, regular monitoring risked some patients becoming dependent on their GP or asthma nurse ‘looking after them’ and taking decisions for them.

10.5.3 Potential of technology to support asthma self-management

*Assistance for older patients to adopt an app*

Most of the professional participants worried that the app would be difficult for older patients. Some were aware that older patients were not usually the majority groups in most of the telehealth interventions for asthma[69, 100] or other studies in healthcare technology[232]. They thought that it may be challenging to attract older people to adopt an app, though there are telehealth interventions which have been able to recruit older people[69]. At the other end of the age range, younger patients may be more interested in the app, and in our study, we had recruited more participants in the ‘over 46 year old’ age group than the 16-25 year old participants. The older patients had more enquires on how to download and use the app, when compared to younger patients. However, by providing sufficient assistance and clear instructions such as providing an enquiry facility on the app, and a telephone and email helpline, older patients learnt quickly and were able to operate the app. This outcome resonated with a recent systematic review on asthma telehealth, which concluded that there was no evidence to show that telehealth was more difficult for people over 65 years[98].
The future of technology supported monitoring.

From my findings, self-monitoring with feedback and advice is one of the most popular supports for both patients and the healthcare professionals. To implement this feature on an app, the technology designer (with clinical advice) needs to choose the parameters to log, decide on thresholds to trigger advice, and determine the advice to be available to patients. Below are some of the example logs, triggers and advice.

Possible triggering parameters:

- **Symptoms and medication usage:** These are the parameters that the past telehealth interventions have used[69] and most of the current asthma apps are using. Diaries of asthma symptoms such as a) wheezing, b) feeling chest tightness, c) feeling breathless, d) coughing, e) waking up at night because of asthma and f) the increasing use of reliever inhalers, are central to existing asthma action plans, and are also widely used in monitoring algorithms (see chapter 3: systematic review). The technology already exists for detection of wheezing, chest tightness, breathless and coughing by the microphone on the phone or wearable gadgets on the chest or even (in the future) implementing nano protein robots in the bronchial tube. Waking up at night (a recognised feature of poorly controlled asthma[173]), can be detected by the phone’s accelerometer tracking patient’s motions in bed, as well as the phone’s microphone actively tracking the patient’s snoring. Although typically used to track adherence to preventer medication (see chapter 3: systematic review), smart inhalers may be better used to detect changes in the patterns of use of reliever inhalers. A threshold has to be developed that will trigger advice. Some of the questions that we need to ask are:

  i) What were the usual patterns of the symptoms for the patient?
  ii) Should we focus on the variation difference or the peak different in different days as the trigger?
  iii) Should we use a single symptom or a combination of those symptoms to trigger the threshold?

Questionnaires such as the Asthma Control Questionnaire or Asthma Control Test provide a validated frameworks to score symptoms and the medication
taken, with suggested thresholds for determining the boundaries of poor control[233,234]. The simpler Royal College of Physician three questions has been shown to be able to detect poor control and may be a more practical option to be used to determining the boundaries[173]. These questionnaires all require patients to input symptoms regularly, which very few of the patients in my study continued to do. Therefore, it is suggested auto detection of symptoms and reliever use would reduce the efforts on the patient and avoiding missing data in manual logs. However, this auto logging may reduce patients’ intuitive awareness of their asthma and engender over-dependence on the app.

- **Peak flow**: This is the parameter that most of the past telehealth interventions have used[69] and most of the current asthma apps are using. Peak flow is also a key parameter used in many asthma action plans[36]. Deteriorating asthma control can be detected when there is an increase of morning to evening peak flow variation, or a significant drop from the individual’s usual, or ‘best’, peak flow values. The normal value of peak flow depends on an individual’s height, age and gender. A peak flow meter is a handy, portable device for patients to use at home and can be electronic or mechanical. Some electronic peak flow meters are able to transfer the measurement to an app, thereby reducing the risk of inaccurate data entry. Before using the meter, patients must be trained on the measurement technique because wrong peak flow technique (e.g., tongue blocking the mouthpiece of the meter, not giving a short hard blow) affects the accuracy of the measurement and leads to an incorrect interpretation of the asthma control data[8]. In past telehealth interventions, some have used peak flow measurements with symptom scores and the use of a reliever inhaler as the parameters to trigger advice[69] using algorithms based on guideline recommendations for self-management[24]. My systematic review suggested that these interventions were as effective as the more traditional paper plans approaches[69]. Nowadays, most of the asthma apps in the market use peak flow and the standard EN13826 scale[235] to trigger advice. Therefore, using peak flow is feasible and an option for triggering action for patients who wish to monitor their asthma in this way, but the technique needs to be checked.
• **Unusual prescription ordering:** warnings of unusual ordering of repeat prescriptions are already available on the practices’ computer platforms (section 9.6), but this is facility is not linked with the pharmacy computer systems and currently does not communicate with patients’ apps. Future systems could link with repeat prescription ordering systems and provide warnings if usages had increased or decreased. Alternatively, the app could link with systems for monitoring use of inhalers and provide alerts that the inhaler is low and will soon need renewing. Reminders to renew inhalers have proved effective in establishing improved levels of app adherence[236]

• **Pollen count and other environmental factors:** pollen, temperature and humidity are the triggers for some asthma patients. Many of our participants wanted to see how their asthma was affected by these environmental parameters, and to get some advice on what to do. High pollen count warnings, as well as details of temperature and humidity in particular areas, are already available on the Met Office app. Therefore, it is feasible to implement triggering algorithms and pop up advice with these parameters. For research, or to enable patients to learn about their own asthma triggers, mapping the asthma exacerbation rate with the environmental factors in different areas is also feasible, providing of course that patients give consent to use their data.

• **Diary, tweets and posts on social media:** some patients used the diary to record how they felt about their asthma, their symptoms and peak flow, whilst other patients shared their asthma diary on social media. One patient participant suggested using free text or even pictures to record their condition. Therefore, the diary and posts contain the traceable elements to detect the patient’s condition. However, free style logs increase the complexity of extracting useful parameters for triggering advice. For example, if patient posts ‘I feel sad today’, we do not know if she is sad because of her asthma or something else, and just how sad is sad anyway? These logs have potential to be triggering parameters but more research is needed to look at the feasibility of this option.
Choice of advice:

Different patients want different advice. Designers should consider which advice is the best for their target group of patients.

- **Standardised asthma action plan advice**: asthma action plans are used to provide safe advice for asthma patients. The advice includes medication adjustment, when to visit the GP or asthma nurse and when to call 999 for an emergency. The template is generic; however, the trigger, peak flow value and the dose of medication to be taken are customised for different patients. The values are decided and agreed by the patient and their healthcare professional during a consultation. This action plan was wanted on the app by most of our participants, though some patients did not use the action plan because they felt it had not been sufficiently customised advice for them. The template is fixed and for everyone even if they had well controlled asthma and seldom experienced exacerbations.

- **Personalised advice**: some patients wanted some other, more practical advice on their daily management to be on the plan. For example, one patient had exacerbations because of dry air on a plane, and their GP had discussed ways to increase humidity by using a damp towel to cover their nose and mouth. Others wanted specific advice specifically on managing exercise induced symptoms according to whether they wanted to undertake light or heavy exercise. Therefore, they wanted to see this type of day-to-day advice on the plan as well.

- **Advanced advice**: some patients were looking for more advanced advice. They suggested that they knew themselves well and that they did not need an app to tell them that their symptoms were getting worse, and that they needed to adjust their medication or arrange a GP or nurse appointment. This group of patients was made up of frequent users of technology, not only for mobiles but also computers and many had a high educational level. They wanted the app to advise them about something they did not know about, for example, their exact triggers and unusual exacerbation rates in their area.
10.5.4 Legislation: a barrier versus necessary safety regulation

The need to ensure patient safety whilst enabling the rapid technological innovation requires discussion between all stakeholders. A risk matrix as suggested in the ISO 14971[237] may be useful to aid the discussion between different stakeholders. Appendix 24 presents the risk matrix that I have developed from the app developer’s perspective. The matrix provides a structured analysis to determine the risks actually brought, or at least threatened, by the asthma self-management app by employing the features that I found in this study. Other stakeholders can add their thoughts to the matrix in the discussions.

A key perspective is that of the patient who uses healthcare apps. My patient advisory group considered that there was a need to understand how people used the asthma apps before developing legislation to regulate those asthma-focused apps. Others have supported this view, suggesting that any harm was probably due to the way the patients were using the app, rather than the app itself[238]. A specially designed education programme to raise patients’ awareness of the issues of both safety and risk may be a more effective approach to protect patients’ safety.

Currently there is little understanding of the regulations; effective ignorance which leads to different interpretations about the risks from asthma apps, as happened when I requested approval from my University sponsor for my app. The need for these discussions is urgent in order to reach consensus on what constitutes risk in an app, and therefore can result in providing a clear guideline for different stakeholders to follow.
Chapter 11 Implications

In this chapter, I will discuss the implications of my findings as they relate to the healthcare policy, NHS, asthma app design, current legislation and research.

11.1 Implication for healthcare policy

Consider apps as a feasible option that can contribute to strategic objectives

Developing person-centred primary care and strengthening patient engagement in making decisions about their care are core components of the strategic plan from the NHS Lothian in 2014-2024[239] and the 2020 frameworks for action in the UK[240]. Population growth, especially in the elderly, with their long-term health and social care needs, has increased the diversity of healthcare required for different ethnic groups, and therefore the importance of a personalised care model[241]. A key challenge to provide personalised care is to maximise the limited resources available to cater for this growing healthcare demand and to encourage patients to make decisions about their healthcare; in other words, to self-manage. My findings suggest apps might not only support self-management, but could also contribute to the broader aspects of self-management highlighted in the PRISMS taxonomy'. Therefore, apps make up one of the digital solutions that are worth considering when it comes to the delivery of self-management support in primary care.

Encourage data interoperability between platform suppliers

The centralised database is the core element of self-management apps, and the key step to forming a centralised care system is to allow data exchange between the medical practices’ databases. The databases are currently operated by four suppliers (EMIS, TPP, InPS, Microtest) who share the primary care market in the UK. The strategic plan 2015-2020 from the Health and Social Care Information Centre (NHS Digital) has responded to the need for data exchange between those suppliers and the NHS. The NHS set out the vision to build a centralised healthcare system to allow records and information flow between healthcare settings; and they have committed to achieving digital care records that are interoperable in real time by 2020[242,243]. The NHS is also adopting SNOMED CT[64], a standardised protocol for the electronic care records and all systems platforms in primary care must adopted the
protocol before the 1st April 2018. This protocol model is comprised of a standardised vocabulary to assist communication between these four suppliers and the NHS. This protocol will also encourage more technology developers to create healthcare apps because these standardised protocols ease the programming process and will therefore enable small and medium software companies, with relatively limited resources, to engage in this market.

Three other issues regarding interoperability are a) the compatibility of the operating systems in the practices’ computers, b) the firewall setting in the practices’ computer networks and c) the scalability of the systems architecture in practices.

   a) Compatibility: the operating systems of the practices’ computers should be able to run the software code for data transfer. If the Windows operating system cannot support the code, a system upgrade is needed.

   b) Firewall: the firewall setting limits the data to be transferred between the practices’ databases and apps. Appropriate firewall settings are needed for all data transfers, while protecting the practices’ databases from viral attacks.

   c) Scalability: Although most of the structured cabling design has provided 20% extra spaces on the cable rack for future system extension, extra racks may be needed to allow transfer between apps and practices’ databases. If extra racks are needed, extra spaces in the practices will also be needed.

Address the legislative issues raised by self-management apps

Current regulation of healthcare apps is controversial. Safety is important to patients, while risk aversion slows down app development and stifles innovation. To move forward, there is a policy need to prioritise discussions with different stakeholders, particularly: i) medical practices, ii) patients, iii) app developers and iv) legislative and research governance advisors in order to reach a solution that both protect patients’ safety, whilst recognising the need for rapid processes of change.

11.2 Implications for the NHS

Using social media and practice invitation to promote apps

Social media proved very effective at recruiting participants very quickly to use my app, though my study suggests patients are more likely to adopt the app if the social media post is from people they know and trust such as their GP practice. Though
numerically small, the proportion of people responding to the personal invitation from their asthma nurse was greater than that from the social media and people recruited by their practice tended to adhere to monitoring the app for longer than that from the social media.

Easy and immediate access to download, supported if necessary, is the key to triggering adoption. Learning from this, digital initiatives in the NHS should consider a duel promotion strategy: i) utilising social media but ii) also promoting personal invitations from trusted healthcare professionals, as well as providing easy ways to access download. The latter could be achieved by making good use of direct links on promotion material, in order to attract a broader range of patients.

Caveats on promotion of the self-management app to asthma patients

When promoting a self-management app to patients, there are some caveats. Firstly, not all patient participants would like to use apps, therefore, the role of the app should be an optional tool to assist or encourage patients to look after their asthma. Secondly, when promoting an app to patients, it is important to consider patients who are not familiar with technology, in order that patients do not feel ‘abandoned’ by the healthcare system if apps are not tools that they use in their daily lives. Adequate training and support should be provided for patients who are interested in the idea but not familiar with app technology. Promotion should emphasise that the app is not a replacement of their usual care; instead, it is an additional option to assist their asthma management and they can choose if they would like to adopt it or not. The preconceived idea that the elderly are less likely to adopt technology was not supported by evidence from my study. Perhaps their previous experience with technology, and their personal beliefs about apps, influences their decisions more than age; though they may need some support to start using new technology. It is important not to underestimate the adoption from the elderly and so it is equally important not to neglect the elderly in the promotion.

Cost implications: providing sufficient technical support to patients

Users easily give up on an app if they have technical problems when downloading or using it. Some examples of the technical problems that I observed from my study were: a) failure to find the app on app stores, b) failure to download the app because
of insufficient memory space on their mobile, c) failure to download the app because of non-compatible mobile platform, d) failure to save logs, and e) failure to navigate between app’s screens. Therefore, sufficient technical support is needed when implementing a technology-supported asthma self-management initiative based on an app; it is essential that the app is easy to use.

The role of the GP, asthma nurse and practice administration staff is to provide healthcare services, not to troubleshoot technology. Resources are needed either to employ someone who can support / deal with patients’ technical queries or to provide training for, and support the costs of, current administration staff. Employing a third party technology company to centralise the technical queries from different practices could be another option. Further studies are needed to find the most feasible solution to cater for this problem and to explore the associated costs.

11.3 Implications for the asthma app designer

**Features and flexibility**

One size does not fit all and ‘wanted features’ varied between different patients. Older patients usually have more than one long term condition[244] to manage, therefore, a flexible app that caters for different needs for different patients could increase its adoption and adherence.

Clinical action plans, supporting patient monitoring with advice, and providing training for everyday activities, should be the core features of a self-management app because these were the features that patients and professionals stated they would like to see. Other self-management supporting features highlighted in the PRISMS taxonomy could be optional features for patients to choose and download when needed. The application features are:

a) A clinical action plan: an asthma action plan with additional space to enter personalised advice gained after discussion with a GP or asthma nurse. Any updates on the patient’s best peak flow, medication changes and personalised advice after the consultation, need to be automatically entered into the app.

b) Supporting patient monitoring with advice: possible monitoring parameters include i) peak flow, ii) asthma symptoms, iii) medication intake, iv) unusual prescription ordering, v) environmental parameters such as pollen count and
temperature and vi) diary, tweets and posts on social media. Possible advice includes i) standardised ‘actions’ in an asthma plan, ii) personalised advice on their asthma and iii) ‘advanced’ advice to identify asthma. Logging peak flow on a 3-colour graph is a common feedback strategy.

c) Training for everyday activities: i) cross referencing patient’s asthma, ii) daily activity and the environment, iii) predicting possible exacerbations, iv) assisting patients to learn what causes their asthma and v) changing daily activities such as avoiding areas which may trigger their asthma.

d) Others optional features include: i) knowledge bank about asthma, ii) direct links to asthma research (e.g. Asthma UK Centre for Applied Research) and asthma learning material, iii) display of real time pollen count and other environmental factors, iv) low medication reminder, v) appointment booking, vi) repeat prescription and medication ordering, vii) checking inhaler technique, and for occasional patients at risk of sudden severe asthma viii) a panic button to ‘999’.

*Application features to increase motivation for adherence*

From my findings, motivation is the key to maintaining a patient’s adherence. Motivation for patients is enhanced by several factors including: a) personal encouragement from their trusted healthcare professionals, b) contributing to research, c) improving asthma outcome, d) better control of asthma, e) saving time for logging, f) overcoming loss of paper action plan and g) financial incentives. Technology developers are advised to implement features that can maintain or increase patients’ motivation levels regarding app usage. Example features are: a) collaboration with research centre for up-to-date news and to enable (with consent) feedback of patients’ logs to research database; b) use of smart home-assistance gadgets to ask for a patient’s conditions to log data, and c) to facilitate an appointment request to their GP or nurse when the patient needs a review.

*Move from self-monitoring to self-management*

Current asthma apps focus on self-monitoring features (i.e is logging data) as opposed to self-management features (i.e advising on action to take in response to monitored data). Though the legislative requirements require investment of resources in the development stage, the marketing opportunities of a self-
management app should not be omitted. Firstly, digital solutions are needed to provide centralised patient care in the UK, especially for long term condition patients[239, 240]. Secondly, the global annual revenue from mobile health is predicted to reach US $21.5 billion in 2018, annual growth will reach 54.9% in the global market[43]. Lastly, the UK’s asthma self-management app market has not been saturated; only 0.8% of the healthcare apps in 2017 are explicitly for respiratory system conditions[245]. The core elements for optimal asthma management have been clearly identified: i) an action plan, ii) self-monitoring and iii) discussion with healthcare professionals[27]. These three core elements are technically feasible. For example, an action plan can be implemented as text input or using character recognition techniques to import the text from paper based action plans. Patients can enter the monitored data manually on the app or automatically capture it by activity tracking gadgets; online consultations or teleconsultation can be facilitated for patients who cannot go to the practice in person; consultations can be assisted by access to the data logged by patient in daily. Therefore, it is worth app developers considering developing asthma self-management apps.

11.4 Implications for telehealth research

In this study, I combined the stages of the MRC framework and Oxford app development roadmap to develop my app prototype and carry out the feasibility study. This approach is suitable for telehealth interventions because it helped identify the key aspects related to both clinical and technology perspectives during the development stage. For example, in the early stage, the MRC framework recommends identifying clinical evidence, whilst the app development roadmap advises thinking about the user’s wants, and marketing value of the app. Using these two approaches inspired me to conduct a systematic review, social forum analysis, and an app review, to collect the evidence I needed to make decisions on the prototype and the feasibility study’s design.

The flip side of this approach is it did not match the timescale for the development cycle of the app because of the time it took to arrange ethics and governance approvals. This time delay factor is a problem for app developers; however, we cannot omit the ethics requirements because they help us to think
through the ethical impact of the app initiative on its potential users. This is our responsibility when conducting research and also a gesture of respect to our participants. However, I think it is possible to improve the situation. For example, simplifying the application process and allowing researchers to view the process of the review, so that we can plan better for on-going tasks.

For the evaluation stage, which is the next stage of my app prototype, the MRC framework suggests using an RCT to evaluate the app’s effectiveness. However, this approach does not adequately meet the rapidly changing context of apps and technology. This concern is shared by the people who work in clinical trial units. In preliminary findings from a survey in a parallel project within the Asthma UK Centre for Applied Research, conducted by Newby[246], the researchers suggested that we need new methodologies to cater for the dynamic changes of apps. Therefore, in the future, research is needed to develop an appropriate framework with which to evaluate telehealth. In the meantime, we have to be aware that the app market changes rapidly; therefore, to find the best approach to evaluating telehealth, researchers need to work together with technology providers and end users: particularly patients and healthcare professionals. It is also essential to have an open mind regarding the ideas in the market while meeting the prescribed ethical requirements when conducting research in the field of healthcare self-management apps.
Chapter 12 Conclusions

The key questions for my PhD, the research I undertook to answer the questions, my key findings and conclusions are summarised in Table 32.

Telehealth (specifically the use of apps) offers a clinically effective and feasible option for supporting patients’ self-management. However, one size does not fit all and ‘wanted’ features varied. Flexible apps may meet the needs of a broader range of patients: a) clinical action plans, b) supporting patient monitoring with feedback/advice and c) training patients for everyday activities are the core ‘attractive’ and ‘adherent’ features of self-management apps. Although apps are an option to support asthma self-management, they do not replace trusted healthcare professionals. GPs and asthma nurses encourage their patients to adopt and adhere to the app, discuss the advice in the app-based clinical action plan, as well as providing personalised advice on asthma management.

To increase adoption and adherence rates of the self-management app, a dual approach incorporating social media with personal support from trusted healthcare professionals, should be considered, as should be the provision of sufficient technical support. On-going adherence requires on-going motivation, such as GPs’ and asthma nurses’ encouragement and the users’ perceptions of benefit.

Increasingly there are novel approaches available for monitoring patients’ conditions and behaviour, but to move the app from a monitoring device to a support for self-management requires thresholds for triggers to be established and appropriate, clinically personalised advice to be included in the app.

Whilst important for safety, the ‘medical device’ directives are currently a barrier for asthma self-management app development. Discussions with all stakeholders are needed to reach consensus about how to determine the appropriate or acceptable levels of risk and the commensurate necessary legislation. Also further research is needed to develop innovative methodological approaches to evaluating telehealth.
Table 32 Conclusions from the four perspectives

<table>
<thead>
<tr>
<th>Perspectives</th>
<th>Questions</th>
<th>How did I answer the questions in this PhD?</th>
<th>Conclusion</th>
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<tbody>
<tr>
<td>Clinical</td>
<td>What is the current understanding of clinical effectiveness of the mobile technologies to support asthma self-management?</td>
<td>Systematic review</td>
<td>Mobile apps, incorporating an action plan and other self-monitoring features were at least as effective as traditional approaches to support self-management.</td>
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<td></td>
<td>What are the support features that healthcare professionals and patient would like to see on an app to support asthma self-management?</td>
<td>Three months feasibility study</td>
<td>Supporting provision of asthma action plans, monitoring of patients’ conditions with feedback and providing training/rehearsal for their asthma activities were the key ‘wanted’ features.</td>
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<td></td>
<td>What is the role of healthcare professionals when supporting patients with an app?</td>
<td>Three months feasibility study</td>
<td>GPs and asthma nurses triggered adoption and provided motivation to encourage patients to download and continue to use the app.</td>
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<tr>
<td>Patient</td>
<td>What are the supporting and application features that patients would like to see and will continue use on an app?</td>
<td>Online social forum discussion analysis and three months feasibility study</td>
<td>‘Wanted’ features included: logging symptoms, peak flow, and medication use; with warning or personalised advice about what to do when their asthma was getting worse (an asthma action plan); sharing their data with practices, viewing pollen counts and cross referencing their asthma with the environmental data (temperature, pollen count and humidity); connection with fitness or activity tracker.</td>
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<td>We attracted more than 100 participants to download our app though (as with all health apps) the usage rate decreased over time. Reasons for adoption, and motivation to continue using the app included perceived health benefits (better asthma outcomes), personal encouragement from the GP/asthma nurse and helping research.</td>
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<tr>
<td>Perspectives</td>
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<td>How did I answer the questions in this PhD?</td>
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<td>Technology/marketing</td>
<td>What are the available features in the current asthma self-management apps in the app stores?</td>
<td>App review</td>
<td>Information about asthma, self-monitoring with feedback such as the asthma’s severity on a 3 colour zone graph, medication reminders, sharing records with professionals/carers, personalised reminders, booking appointments and logging lifestyle parameters such as mood and food. Current asthma apps focus on self-monitoring features, as opposed to self-management features, though a few include action plans. Key barriers were related to integration with practice systems: a) inability to connect the app with the practices' software platforms, b) lack of seamless Wi-Fi to enable professionals to review logs on their patient’s app and c) inability to transfer advice/feedback to their patient’s app after the consultation. Self-management apps are feasible from a technical perspective, and the asthma self-management app market is not saturated. The structured clinical vocabulary (SNOMED CT) will help the development of the open protocol, which will facilitate better integration between practices' databases and apps.</td>
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<tr>
<td>Legislative</td>
<td>What is the legislative barrier to develop a mobile app to support asthma self-management?</td>
<td>MHRA guideline on medical device stand-alone software, including apps, and impact on our app's development</td>
<td>Risk aversion and failure to differentiate high and low risk technology (specifically the core element of an action plan) hinders the development of self-management apps. There is an urgent need for all stakeholders, including patients, to discuss and reach consensus regarding the legislative approach to apps designed to support asthma self-management.</td>
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Page 268
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